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AERO/SPACE ENGINEERING

REVIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT • MISSILES • ROCKETS • SATELLITES • SPACECRAFT

EVOLUTION OF THE AIR-SPACE INDUSTRY

Guest Editorial by Gen. Orval R. Cook

August /1958

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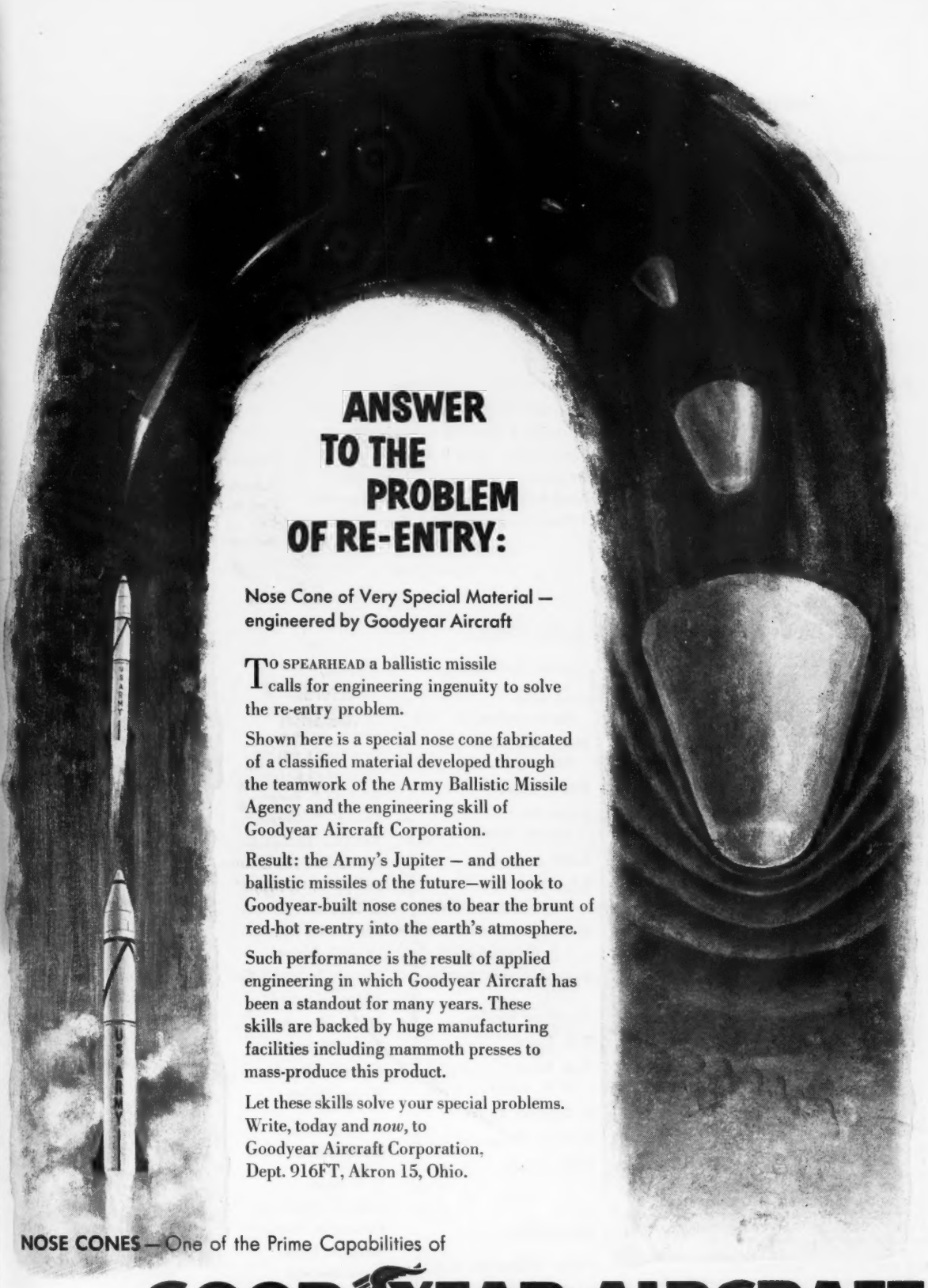

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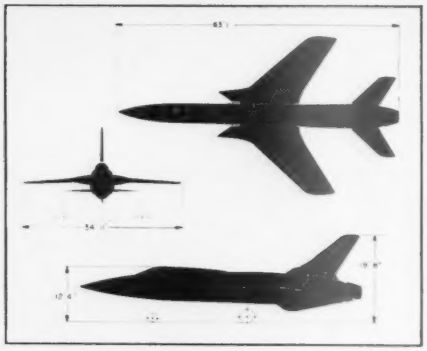

On our cover

A new photo of the Republic F-105 Thunderchief, going into volume production next month, shows the latest model (bottom plane) being refueled. A three-view of the fighter-bomber, which can carry combinations of nuclear weapons, and other stores, is at left. Its flight control system (GE-designed), literally functions as an "electric copilot," Republic has announced. Advanced versions incorporating the all-purpose NASARR monopulse radar system will be able to attack targets through fog and darkness. The internal bomb storage area is a bay longer than that in the World War II Flying Fortress. The first production model was turned over to the Tactical Air Command on May 27. To speed transition of the Thunderchief from test to squadron use, TAC's 335th Squadron of the Fourth Fighter Wing will carry out operational and functional testing at Eglin AFB, Fla., under a new USAF procedure.

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AERO/SPACE ENGINEERING

VOLUME 17 / NUMBER 8 August 1958

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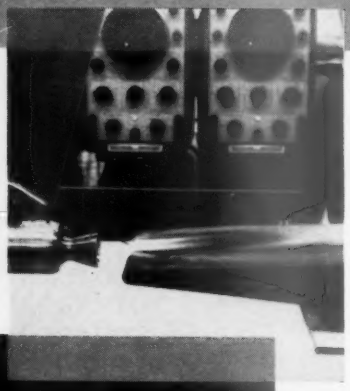

When Temco engineered and developed the aft-fuselage and vertical stabilizer section of Convair's B-58 Hustler . . . the wing section and fuselage panels of Temco's own TT-1 jet trainer . . . the wings of the air-launched "Teal" missile . . . the aircraft industry acknowledged Temco as a leader in development and production of honeycomb sandwich and hi-temperature structures. Missile applications currently programmed are substantial recognition of Temco's stature.

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IAS News

. . . a record of people and events of interest to Institute Members

A. Scott Crossfield Wins 1958 Octave Chanute Award

X-15 Pilot Cited for Contributions to Human Factors of High-Speed, Altitude Flight

THE PILOT chosen to be the first man in space has won the Institute's 1958 Octave Chanute Award. A. Scott Crossfield, North American Aviation Development Engineer and Experimental Test Pilot who will fly the X-15, was presented with the award at the IAS National Summer Meeting last month.

The 37-year-old native Californian was cited for "extended and significant contributions to the knowledge of human factors involved in flight at extremely high speeds and high altitudes."

Mr. Crossfield first flew when he was 6 years old—as a passenger—and, when he was 12, became a student pilot. He said he has always had the intention to fly and that he realized there was a definite pattern to follow to achieve this ambition.

His Formula

"I did what I felt were the things to prepare me best for the things I wanted most. This was to gain experience in several fields, notably engineering, business, aeronautical design, and laboratory work."

He entered the University of Washington in 1940 and, after an interruption during World War II, was graduated with a B.S. degree in aeronautical engineering in 1949. In 1950 he received an M.S. in aeronautical science from the same school. While at school prior to the war, he worked for Boeing Airplane Co. as a Production Expediter.

Mr. Crossfield joined the Navy in 1942 and became a Naval Aviation Cadet at Corpus Christi, Tex. He flew Navy N3N, SNV, SNJ, F4F, F6F, SBD, and F4U aircraft during his service and also was a fighter-type instructor and maintenance officer.

During his postwar college tenure he worked with the University of Washington wind-tunnel staff and was an aircraft accessory designer for Seeger Aircraft Specialties.

By 1950 Mr. Crossfield had accumulated some 2,500 hours flying time in piston-engine aircraft. In June of that year he joined the NACA High Speed Flight Research Station as an Aeronautical Research Pilot.

When he began the Douglas D-558-I Skystreak program, he had but 20 hours in jets, having achieved the transition in an F-84. He spent 5 years with the NACA research aircraft doing "usual research test flying, which is using the airplane to its extreme envelopes."

Preferred D-558-II

His preference ran to the D-558-II in which he became the first pilot to reach a speed of Mach 2 (1,327 m.p.h.), accomplished in 1953. This rocket-powered aircraft had virtually no escape system. He also flew the Convair XF-92A, Northrop X-4, Bell X-1, Bell X-5, and the F-100 in roll coupling test programs.

Mr. Crossfield views the X-15 as the next obvious step in research. Something beyond the X-2 was needed, and the idea was considered by many groups—NACA, the Navy, the USAF; he participated in the NACA effort to determine what this airplane could be. North American's design proposal was accepted by the USAF in 1955, and, in December of that year, he joined the firm.

His job with the X-15 is to obtain operational evaluation in the entire design of the airplane—not solely to fly it. He has formulated the design requirements of the aircraft's escape system and has coordinated engineering and manufacturing plans with responsible offices in the Air Force and NACA.

A. Scott Crossfield

X-15 Objectives

For Mr. Crossfield the X-15 represents the maximum performance in altitude and speed which can be practically attained with a single-stage vehicle, with existing fabrication methods, materials, and in the shortest time with the best economy. The X-15, he says, will investigate three regions: stability and handling qualities at extreme speeds and altitudes; handling qualities for extra-atmospheric flight; and the effects of aerodynamic heating on an airframe.

In addition to his research flying, he has been active in the study of human factors and has given considerable attention to problems of developing a pressure suit. He was a consultant to the Navy in the operational development of its full-pressure suit, which he personally tested under extreme conditions of heat, cold, and pressurization in altitude and heat chambers.

He also subjected himself to complex acceleration forces in tests at the Naval Air Development Center to obtain data on a pilot's reaction to emergency conditions that could be met in flights at supersonic speeds.

The IAS Award, a certificate and honorarium, is given annually for "a notable contribution made by a pilot to the aeronautical sciences." Last year's winner was Lt. Col. Frank K. Everest, Jr., who was cited for developing Bell X-2 flight test techniques.

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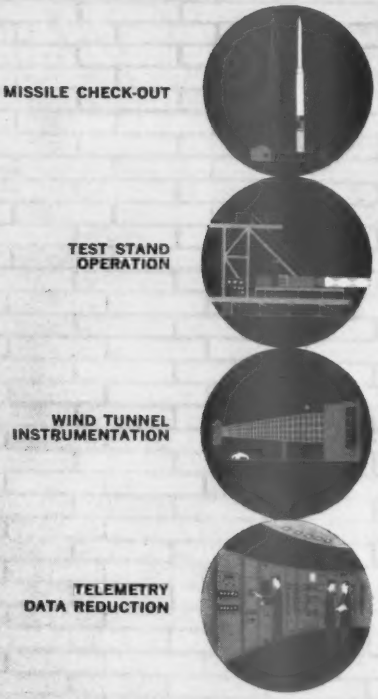

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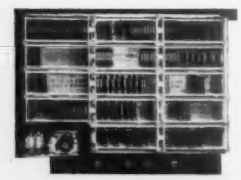

For technical information on automatic test control and data reduction with the RW-300 and with special digital systems which utilize solid-state components exclusively, write: Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, P.O. Box 45607, Airport Station, Los Angeles 45, California, or call OSborne 5-4601.

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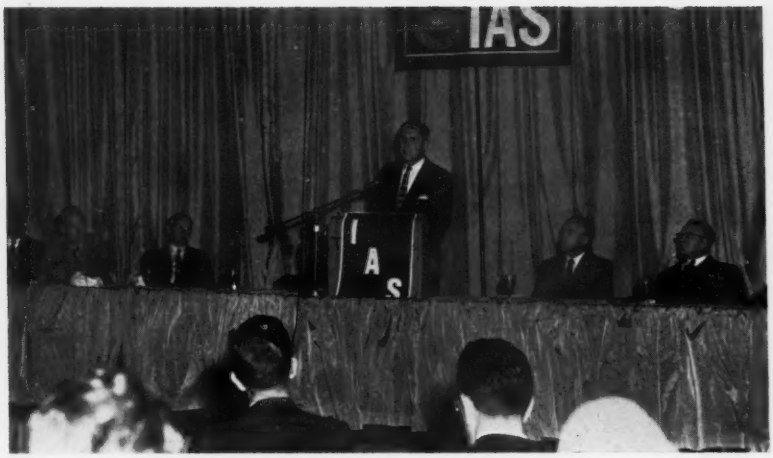
May 12 luncheon speaker was Rear Adm. K. S. Masterson, Director, Guided Missile Division, Office of Chief of Naval Operations.



The Honorable William M. Holaday (*standing*) was principal speaker at the dinner. Other guests at the head table are (*left to right*): R. H. Charles; Brig. Gen. William B. Bunker; J. S. McDonnell; Edward C. Wells; and Rear Adm. Selden B. Spangler.

1,000 Members Attend Guided Missiles Meeting

By John F. Yardley*

THE IAS National Midwestern Meeting on Guided Missiles in St. Louis, May 12–14, was attended by some 1,000 members.

Featured were classified sessions on propulsion, guidance and control, engineering management in missile development, operational analysis, aerodynamics and ballistics, composite design, astronautics, structures, and aerodynamic heating.

May 12 luncheon speaker was Adm. K. S. Masterson, Director, Guided Missile Division, Office of Chief of Naval Operations. Navy missile weapons systems in use and under development was his topic.

Colonel Edward M. Hall, USAF Ballistic Missile Division, ARDC, spoke at the May 13 luncheon on the development of modern weapon systems.

Some 600 members and guests attended the May 12 dinner, the only unclassified gathering of the meeting. The Honorable William M. Holaday, Director of Guided Missiles, Department of Defense, spoke on "The Future of Guided Missiles." He reviewed current and future missile programs and stressed the importance of keeping all aspects of national defense in true perspective.

Leo Mirowitz, Chairman, St. Louis Section, was dinner host. IAS President Edward C. Wells, Toastmaster, introduced members and guests seated at the head table as follows: Vernon Outman, Meeting General Chairman; S. Paul Johnston, IAS Director; Capt. T. W. Collins, BuAer, St. Louis; Robert H. Charles, Executive Vice-President, McDonnell Aircraft Corp.; Rear Adm. K. S. Masterson; Maj. Gen. James F. Phillips, USAF (Ret.), Aircraft Industries Association; Brig. Gen. William B. Bunker, U.S. Army Transportation Supply and Maintenance Command; J. S. McDonnell, President, McDonnell Aircraft; Rear Adm. Selden B. Spangler, Naval Air Development and Materiel Center; Kendall Perkins, Vice-President—Engineering, McDonnell Aircraft; Col. Edward M. Hall; B. G. Bromberg, McDonnell Missile Chief Engineer, and Chairman, Technical Program Committee; and Mr. Holaday.

Included in the program were field trips to McDonnell Aircraft Corporation's laboratories and assembly lines and a ladies' program.

The St. Louis Section of the Institute was meeting host. McDonnell Aircraft loaned auditorium space for the technical sessions and luncheons.

Some of the St. Louis Section members who contributed to the success of the meeting were: Mr. Outman; Mr. Bromberg; E. M. Flesh, R. E. Roth, C. H. Perisho, A. D. Massey, and R. R. Stephens—all of whom were Arrangement Committee Chairmen and Vice-Chairmen; Lt. Comdr. A. J. Geel and T. M. Bellan, Security; and F. H. Roever and Margaret Bernard, Semi-Technical Programs.

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* Project Engineer, McDonnell Aircraft Corp.

Colonel Edward M. Hall, Air Force Ballistic Missiles Division, ARDC, spoke at a luncheon on May 13.

Leo Mirowitz, Chairman, IAS St. Louis Section, which was host for the meeting, was official welcomer.

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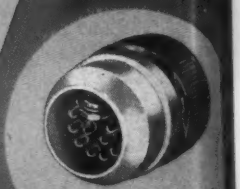
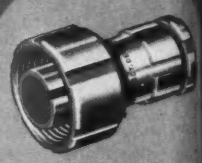
weatherproof cannon plug



Potting type. For weather proofing with sealant material.



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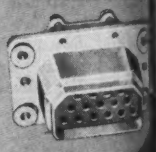

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AHS FOURTEENTH NATIONAL FORUM HELD APRIL 16–19

Honors Night Draws 900

Some 900 members and guests turned out for the Honors Night Dinner of the American Helicopter Society's 14th Annual National Forum, April 16–19, at the Sheraton Hall Hotel, Washington, D.C.

Honors presented at the April 17 dinner included the Dr. Alexander Klemin Award, the Society's highest honor, given to Friedrich L. von Doblhoff, Chief Helicopter Engineer, McDonnell Aircraft Corp., and the Captain William J. Kossler Award, accepted by Lt. Col. Charles E. Hollis for the U.S. Army's Transportation Aircraft Test and Support Activity. This was given "for greatest achievement in practical application or operation of rotary wing aircraft, the value of which has been demonstrated in actual service during the preceding year."

Recipients of AHS Honorary Fellowships were Rene H. Miller, Professor, Massachusetts Institute of Technology, and Col. Robert R. Williams, President, U.S. Army Aviation Board. The citation was made for having "distinguished themselves by notable and meritorious service in the advancement of rotary wing aeronautics."

New Officers

New AHS officers for the 1957–58 term were introduced at the Membership Luncheon on April 18. They are: President—Charles H. Kaman, President and General Manager, The Kaman Aircraft Corp.; Secretary—Leon L. Douglas, Vice-President—Engineering, Vertol Aircraft Corp.; and Treasurer—Donald M. Thompson, Chief, Engineering and Development Branch, Army Aviation Div., Office, Chief of Transportation. New England Vice-President—Michael J. Theodore, Assistant Project Engineer, Sikorsky Aircraft Division, United Aircraft Corp.; Mideast Vice-President—Newby O. Brantly, President, Brantly Helicopter Corp.; Midwest Vice-President—Jack E. Leonard, Manager, Military Requirements, Helicopter Division, Cessna Aircraft Co.; Southwest Vice-President—Elton J. Smith, Flight Test, Bell Helicopter Corp.; Southeast Vice-President—George W. Fey, Sikorsky Washington Representative; and Western Vice-President—Paul C. Thornbury, Air Carrier Safety Inspector, CAA.

Technical Sessions

Technical Chairman for the Forum was Professor Miller. Sessions were held on April 17 and 18. They included the following subjects: VTOL Aircraft, Operations, Theory and Test, and Tip Jet Propulsion. Proceedings of the Forum may be obtained by writing to the Executive Secretary, AHS, 2 E. 64th St., New York 21, N.Y. Price is $4.00 for members and $6.50 for nonmembers.

The Forum also included a Technical Trade Exhibit and an Air Show in which 22 different types of rotary wing aircraft took part.

Friedrich L. von Doblhoff *(right)* was presented the American Helicopter Society's highest award—the Alexander Klemin Award—by Jack E. Leonard, AHS Vice-President.

1958 WATER-BASED AVIATION AWARD

Won by Navy BuAer Scientist

Frederick W. S. Locke, Jr., Assistant Director of the Navy Bureau of Aeronautics Research Division, has won the Institute's 1958 Water-Based Aviation Award.

The award was presented to him at the IAS National Summer Meeting held last month in Los Angeles. He was cited for "outstanding analyses, design studies, and hydrodynamic test programs resulting in improved performance for seaplanes."

The award was established at the 1957 Annual Meeting in memory of Edwin C. Musick, pioneer of overseas air transport routes, who was killed in 1938 while in command of the first commercial flight from the United States to New Zealand. Designed to stimulate water-based aircraft research, the award is given "for meritorious work in the design or operation of water-based aircraft leading to advances in performance or utility."

Mr. Locke pioneered the development of techniques for conducting tests on small models of flying boat hulls to determine such hydrodynamic characteristics as spray, porpoising, directional stability, and rough water behavior. This was done at the Stevens Institute of Technology Experimental Towing Tank between 1937 and 1944.

In the latter year he became a hydrodynamic consultant in the Research Division of BuAer, where he assisted in design studies which led to the XP5Y-1.

Frederick W. S. Locke, Jr.

A prolific worker at both Stevens and BuAer, Mr. Locke has authored or coauthored some 75 reports on seaplanes and numerous others that are classified. He has made important contributions in the following spheres: towing tank tests,

(Continued on page 112)

NEW limit switchless actuators

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- **C** *Rotor Blade Trim Actuator*
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- **H** *Rudder Trim, AVRO CF-105*
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DETROIT STUDENT CONFERENCE
Held at Michigan University

The Detroit Regional Student Conference was held May 6 at the University of Michigan, Ann Arbor.

Judges were John T. Burns, General Manager, Sales and Service, Aerohydraulics Division, Vickers Inc.; Lovell Lawrence, Jr., Technical Director, Redstone System Coordination Office, Missiles Division, Chrysler Corp.; and Oliver E. Rodgers, Engineering Manager, Utica Division, Curtiss-Wright Corp.

First prize was won by William D. Clifford, University of Detroit, for his paper "Effect of Air Temperature on Vortex Shedding Behind Cylinders."

Bert Hilburger, University of Michigan, won second prize for a paper on "Inertial Guidance."

Third prize went to William A. Stevens, Wayne State University, for his paper "Hydroduct Propulsion."

William D. Clifford, first-prize winner

ST. LOUIS REGIONAL CONFERENCE
Presents Seven Student Awards

Highlights of the St. Louis Regional Student Conference, April 18–19, were the presentations of seven student awards and three Section awards.

Conway Briscoe, Chairman, St. Louis Airport Commission during its expansion program, was recipient of the Section's first award for the outstanding contribution toward the progress of aviation in the St. Louis area. He received the award for his contribution toward the building of the expanded airfield and new terminal.

The second award, for a notable contribution to the aeronautical sciences, went to John F. Mello (A), Missiles Division, McDonnell Aircraft Corp., for his work on missile re-entry problems.

Both awards, brass-on-wood, engraved plaques, were presented by Section Chairman Leo I. Mirowitz.

A third award was presented to Section member Parnell Schoenky for the most notable contribution to the St. Louis Section activities, 1956–57. Mr. Schoenky's contribution was to the Section's TV series and 1957 Model Contest.

Rear Adm. Lloyd Harrison, USN (Ret.), an IAS Associate Fellow, presented seven student awards as follows: First prize to George Michos, University of Kansas, for a paper on "An Experimental Investigation of Internal Compression Intake Nozzles with Perforated Walls."

Second prize was won by Richard Monical, University of Wichita, for his paper "An Experimental Investigation of the Magnus Effect."

Alfred Uhalt, Jr., University of Illinois, received two awards: third prize for a paper on "The Feasibility of and Problems Associated with the Establishment and Logistic Supply of a Manned Earth Satellite" and for the best oral presentation.

Three honorable mention awards were presented to: True Cousins, University of Kansas, for his paper "Understrength Design of Aircraft Structure"; Thomas A. Littmann, Washington University, for his paper "Factors Affecting the Tensile Strength at Elevated Temperatures"; and Paul D. Van Fleet, University of Kansas, for his paper "The Design and Laboratory Analysis of an Air Lubricated Thrust Bearing."

Mr. Michos's award was presented by John Aura Parcel, Vice-President and Director, Sverdrup & Parcel, Inc.

Some 123 members and guests then heard the principal speaker, Rev. Paul C. Reinert, S. J., President, St. Louis University, speak on "The Long Shadow of Our Educational Past." He pointed out that an overemphasis has been placed on improving educational "methods" to the detriment of educational "means" and subject material and offered three solutions to this problem.

A large assist was given to the St. Louis Section's conference efforts by the following companies: Aero Engineering Co.; Allison Division, General Motors Corp.; Emerson Electric Manufacturing Co.; General Electric Co.; Harris-Hanson Co.; McDonnell Aircraft Corp.; Minneapolis-Honeywell Regulator Co.; Sverdrup & Parcel, Inc.; and Westinghouse Electric Corp., Baltimore Division.

Necrology

Karl J. Fairbanks

The Institute has received news of the death of Karl J. Fairbanks (AF) on June 8 at Yonkers, N.Y. A Vice-President and Director, Fairchild Data Devices Corp., Mr. Fairbanks was 55.

He also was a Vice-President and General Manager, Sherman Fairchild & Associates, Inc. He joined Fairchild in 1944, after 4 years with Brewster Aeronautical Corp. where he began as a Design Engineer and rose to Engineering Manager, Long Island City plant.

From 1924 to 1940 he was associated with the NACA Langley Laboratory, Consolidated Aircraft Corp., Aviation Corp., and Edo Aircraft Corp. He was a faculty member of New York University from 1930 to 1939.

Mr. Fairbanks received a B.S. degree in aeronautical engineering from the University of Michigan in 1924 and an M.S. from New York University in 1937.

He was a collector of gems and minerals which he mined himself and was a member of the Westchester Gem and Mineral Society. He also belonged to the Echo Bay Yacht Club, New Rochelle, N.Y., and the American Ordnance Association.

George H. Hauser

The Institute has learned of the death of George H. Hauser (M), Assistant to the President, Republic Aviation Corp., on May 26. He was 62.

Mr. Hauser was a 1917 graduate of New York University where he studied mechanical engineering. From 1918 to 1923, he was Production Manager at Curtiss Aeroplane and Motor Corp. of Garden City, N.Y. Later he held executive positions with Chance Vought Corp., Builders Flooring Co., A&S Tool Works, Inc., and the Kirkham Engineering and Manufacturing Corp.

Mr. Hauser was Executive Vice-President of Liberty Aircraft Products Corp. from 1940 to 1957, when he was elected President.

He won the N.Y.U. Alumni Meritorious Award for 1944 and in 1950 received an honorary Doctor of Laws degree from this school.

Mr. Hauser served on many civic and community organization posts.

Hollis H. Schunter

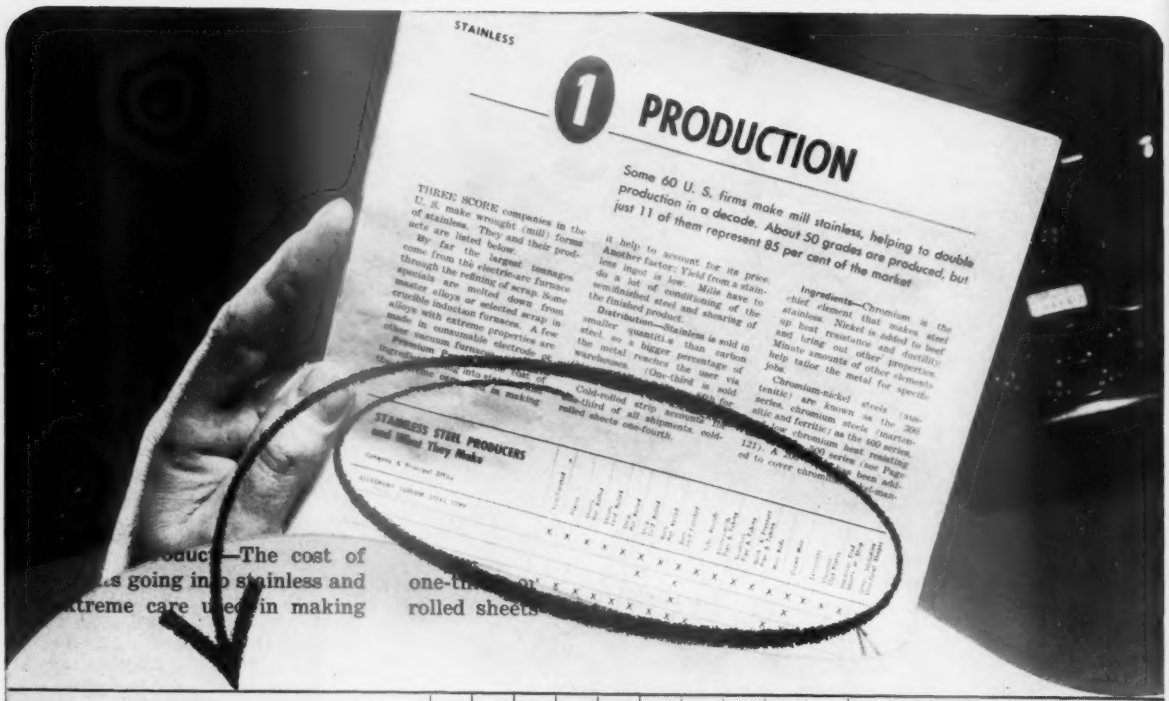
The Institute has received news of the death of Hollis H. Schunter (M) at Hereford, Tex., on February 2. He was 47.

Mr. Schunter had been interested in all phases of aviation and, at the time of his death, was owner and operator of Val Air of Hereford and Hereford Flying Service. He had been in the aerial crop dusting business since 1954.

Prior to forming his own company, he was a meteorologist for Pan American World Airways (Brownsville, Tex.) which he joined in 1941.

Mr. Schunter received his first pilot ating in 1938 and a year later entered

Experience**—the added alloy in **A-L Stainless, Electrical and Tool Steels


STAINLESS
1 PRODUCTION
Some 60 U. S. firms make mill stainless, helping to double production in a decade. About 50 grades are produced, but just 11 of them represent 85 per cent of the market
THREE SCORE companies in the U. S. make wrought (mill) forms of stainless. They and their products are listed below.
By far the largest tonnages come from the electric-arc furnace through the refining of scrap. Some specials are melted down from master alloys or selected scrap in crucible induction furnaces. A few alloys with extreme properties are made in consumable electrode or other vacuum furnaces.
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Mech. & Pressure Pipe & Tubing
Wire Rods
Drawn Wire
Extrusions
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Of the 60 producers of stainless steel...

only ALLEGHENY LUDLUM makes all sizes, shapes, finishes and analyses

In its November 4, 1957 issue, STEEL magazine published a complete run-down on the stainless steel industry. This article reveals that *only Allegheny Ludlum*, of the 60 some companies making stainless, produces all sizes, shapes, finishes and analyses.

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Allegheny Ludlum follows the product from the melt through to finished form, has greater quality control over the stainless you buy. And since A-L makes all forms of stainless, you get unbiased recommendations as to what is best for your individual needs.

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Boeing School of Aeronautics, Oakland, Calif., where he majored in meteorology. He also served for 6 years in the Navy.

He was a member of the American Meteorological Society.

Donald C. Voelker

The Institute has learned of the death of Lt. Donald C. Voelker, USN (A), on April 15 near Tucson, Ariz. He was 26.

Lieutenant Voelker had been Electronics Officer in Attack Squadron 55 stationed at San Diego, Calif.

He was graudated from the Woonsocket, R.I., High School in 1948 and a year later entered the Naval Academy. He received a B.S. degree in electrical engineering from the Academy in June, 1953.

Avco Research Laboratory Is New Corporate Member

The Avco Research Laboratory (a division of the Avco Manufacturing Corp.) has joined the IAS as a Corporate Member.

Located at Everett, Mass., the Laboratory conducts theoretical and experimental research in high-temperature gas dynamics and hypersonic flight. It was created 3 years ago to obtain an understanding of the fundamental parameters affecting reentry of IRBM and ICBM nose cones.

Recently a new type of wind tunnel, using arc-heated air, was installed and is being used in materials research and basic studies of physical processes such as ablation.

Closely related to the re-entry heating problem is the chemical physics of the upper atmosphere upon which area Avco has conducted considerable research.

During the past 2 years, research has been conducted on manned satellites; as a result, conceptual designs have been developed which use a parachute recovery technique.

In addition, research in magnetohydrodynamics (MHD) has been carried on.

Membership Committee Adds Three to Its Staff

Three Members have been named to the IAS National Membership Committee. They are A. W. Gilmore (M), Head, Aerophysics Group, Grumman Aircraft Engineering Corp.; Earl P. Osborn (AF), Applied Loads Engineer, also of Grumman; and E. P. Pillsbury (M), Chief Engineer, Guided Missiles Division, Fairchild Engine and Airplane Corp.

The Membership Committee is the group responsible for evaluating the acceptability of applicants for IAS membership and for determining grades to which they will be elected.

Five IAS Members in Reorganized Firm

The newly reorganized National Research and Development Corp. boasts five IAS members on its staff. Ronald C. Wakeford (M), Director, Technical Operations, General Astronautics Corp., is Vice-President and a Director. Frederick C. Durant, III (AF), Staff Member, Arthur D. Little, Inc., also is a Director.

On the consulting staff are Willy Ley (M); Paul Sandorff (M), Associate Professor, Aeronautical Engineering, M.I.T.; and Otto C. Winzen (A), President, Winzen Research, Inc.

1959 Nuclear Congress to Be Held April 5–10

The IAS again will join the many engineering societies sponsoring the 1959 Nuclear Congress—to be held at Cleveland, Ohio, from April 5–10.

The Congress will be composed of four parts: The Nuclear Engineering & Science Conference, the Hot Laboratories & Equipment Conference, the Atomic Energy Management Conference, and the Atom-fair display of nuclear equipment.

Aero-space engineers and scientists who would like to present technical papers are invited to submit outlines before October 1, 1958. Summaries of from 300–500 words should be submitted to the secretary of any one of the sponsoring societies.

IAS *News*

News of Members

Neil Burgess (AF) has been named Manager of General Electric Company's newly organized Commercial Engine Operation. An IAS Vice-President, Mr. Burgess had been Manager, J-79 Project. Both departments are in the firm's Aircraft Gas Turbine Division.

Jack P. Davey (A), Sales Manager, Aeronca Manufacturing Corporation, Baltimore facility, has been allotted patent rights to the trademark "Digidac" in recognition of his part in development of that line of proprietary company products.

Alfred M. Feiler (M), formerly Head, Special Projects Department, of the Hughes Tool Company's Aircraft Division, is Manager, Advanced Systems Development Division, Cleveland Pneumatic Industries, Inc., Beverly Hills, Calif.

Brig. Gen. Don D. Flickinger, USAF (AF), has been appointed to a newly established position as Special Assistant for Bio-Astronautics, Deputy Commander for Ballistic Missiles at ARDC's Air Force Ballistic Missile Division, Inglewood, Calif. General Flickinger had been Commander, ARDC European Office.

Najeeb E. Halaby (M) has been appointed Vice-President in charge of Finance and Administration and elected a Director of Servomechanisms, Inc. Mr. Halaby was previously Vice-President in charge of company development. In his new position he will be in charge of the Administration, Treasury, and Accounting activities, as well as Personnel, Facilities, Public Relations, Advertising, and legal functions.

Frederick C. Hall (A), formerly an Aerophysics Engineer, Convair (Ft. Worth) Division, General Dynamics Corporation, has joined the faculty of Texas A&M College as Associate Research Engineer. He is Manager, 7 × 10 Low-Speed Wind Tunnel.

Alvin Hittner (M), formerly Senior Stress Engineer, All American Engineering Co., Wilmington, Del., has joined the Naval Air Engineering Facility, NAMC, Philadelphia, Pa., as Mechanical Engineer.

Evert C. Hokanson (AF) has announced the formation of Components Corporation (engineering service and sales), formerly Control Components Company. Mr. Hokanson was a partner of the original firm.

Jerome Lederer (F), Director, Flight Safety Foundation, Inc., and the Cornell-Guggenheim Aviation Safety Center, was presented with the first Monsanto Aviation Safety Award by the Aviation Writers Association for having made 1957's "most significant and lasting contribution to aircraft operating safety."

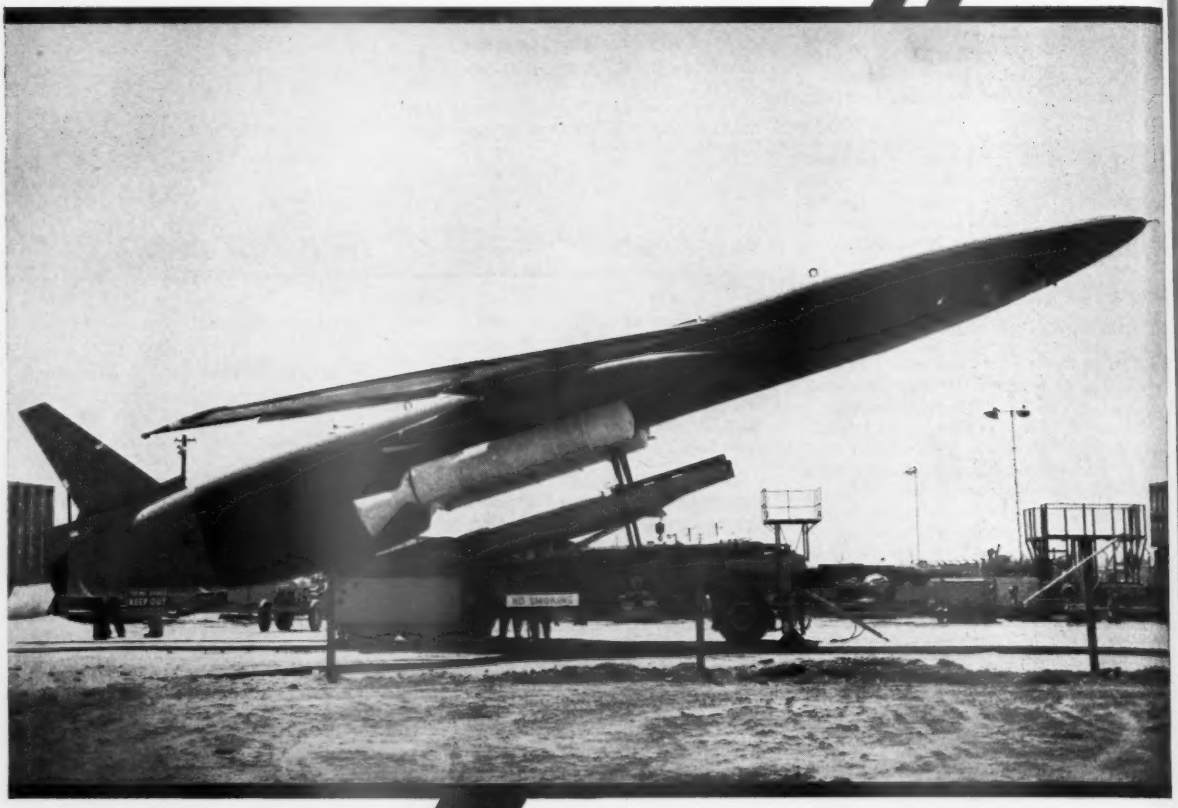
Ralph C. Lenz, Jr. (M), Chief, Plans Division, USAF Wright Air Development Center, has been granted a Sloan Fellowship at Massachusetts Institute of Technology's School of Industrial Management.

Edwin A. Link (AF), President, General Precision Equipment Corporation, has been appointed to the executive committee of the Flight Safety Foundation.

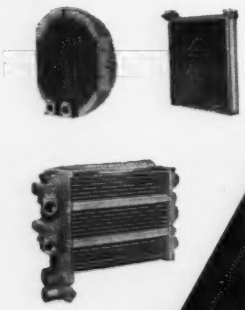
Robert K. Lowry (M), formerly Sales Engineer, The Thorson Company, Los Angeles, Calif., has joined Chicago Aerial Industries as Western Regional Manager

Allen F. Donovan (AF), Vice-President, Space Technology Laboratories Division, The Ramo-Wooldridge Corp., has been cited for outstanding service to the Air Force. This was for his contributions as a member of the Aircraft Panel, Scientific Advisory Board to the Chief of Staff, from 1949–1957. The citation was a letter of appreciation signed by the Board Chairman James H. Doolittle.

Checks heat on the Snark!



Harrison aircraft oil coolers—another quality product of General Motors research in the field of thermodynamics.



Quality qualifies Harrison for the rugged job of cooling Northrop guided missile!

The Snark blasts off in an inferno of heat—but Harrison keeps temperatures down to earth. With a trans-oceanic range, effective heat control over the engine oil is a *must* for this spectacular pilotless bomber. And Harrison heat exchangers were selected to do the job. Harrison's 47 years' experience in the heat transfer field delivers a top-quality product that's rugged and reliable—designed by General Motors engineers to *assure* dependable performance under the most severe operating conditions. That's why you'll find Harrison heat exchangers on so many of America's first-line weapons of defense—on land, at sea, and in the air. If you have a cooling problem, look to Harrison for the answer.

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Norman Meyers (M) has joined Lockheed Aircraft Corporation, Missile Systems Division as Staff Research Specialist. He formerly was Senior Project Engineer, Stratos Division, Fairchild Engine and Airplane Corporation.

Paul W. O'Mearer (M), formerly Project Engineer, nuclear-powered bomber and Bomarc weapons system, Air Materiel Command, has joined the Command's Ballistic Missile Office in Inglewood, Calif., as Assistant for Production Engineering on Guidance Systems.

I. Nevin Palley (AF) has been promoted to Senior Vice-President, Temco Aircraft Corporation. Mr. Palley had been serving as Vice-President, Engineering.

L. Eugene Root (F), Lockheed Aircraft Corporation Vice-President and Manager, Missile Systems Division, was honored by the College of the Pacific, his alma mater, with an honorary Doctor of Science degree. Mr. Root also is an Institute Vice-President.

Earle Stewart (AF), a former IAS National Council Member and Chairman, IAS Philadelphia Section, was appointed Executive Vice-President, Vanguard Air & Marine Corp.

Arthur R. Weckel (M), Vice-President, Sperry Gyroscope Company Division of the Sperry Rand Corporation, has been named head of his firm's new Customer Service Division.

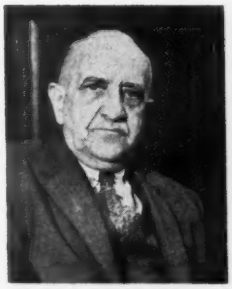
Major Gen. Donald N. Yates (M), Air Force Missile Test Center Commander at Cape Canaveral, has been awarded the Navy's Legion of Merit for contributions to the Vanguard satellite and Polaris missile efforts. Secretary of the Navy Thomas S. Gates, Jr., presented the medal at a ceremony in the Pentagon.

Jesse H. Zabriskie (AF), formerly Director, Customer Relations, Bell Aircraft Corporation Special Weapons Division, has been appointed Assistant Manager, Systems Test Department in Boeing Aircraft Company's Pilotless Aircraft Division.

Ira G. Ross, an IAS Associate Fellow and Eastern Area Council member, has been elected President of Cornell Aeronautical Laboratory, Inc. He has been the firm's Executive Vice-President and Director.

Meet the Staff

An Aero/Space Engineering feature on personnel of the Institute of the Aeronautical Sciences



Walter E. Wills — *Printer*

Probably few in the IAS family have felt the steady growth in Institute membership more than Walter E. "Wally" Wills. As head (and founder) of the Printing Department, he supervises production of most of the literature sent via special mailings to IAS members. In 1946 an average mailing was 8,100 pieces; today the figure is 17,000.

Starting from scratch in 1946, the 69-year-old native Brooklynite equipped his department with the following machines: two multilith, two multigraph, a folder, a ditto, a cutter, and two graphotype. He also is in charge of the addressograph and mailing departments. This includes 25,000 mailing address plates, two addressograph machines, and a postage meter. In addition, "Wally" has special duties as "Traffic Cop" at IAS Annual Meetings.

He says his department can turn out 30,000 single sheets of printed copy per day when necessary. Included in this is such material as Institute Section notices, stationery, and National Meeting literature, cards, forms, etc.

"Wally" has 38 years' experience as a pinochle player—with the same group of friends—in addition to his 45 years in printing. He formerly was associated with the Spencer-Trask Company of Wall Street and the American Writing Machine Company, A Remington-Rand subsidiary.

"Wally" is married to the former Helen F. Johnson and has a son and four grandchildren.—L.S.

IAS *News* — *Corporate Member News*

• **Aerojet-General Corporation's** new junior JATO has been issued an Aircraft Engine Type Certificate No. 250. The 250-lb. thrust solid rocket engine is designed for stand-by use, singly or in multiples, on single- and multi-engine aircraft up to 10,000 lbs. gross weight, according to the company.

• **Allison Division, General Motors Corporation,** has reorganized its Aircraft Engineering Department, expanded its Research Department, and formed a new Missiles Systems Department. James E. Knott, former Assistant Manager, Sales and Contracts, was named Assistant Director of Engineering. Charles J. McDowall, former Chief Engineer, Advanced Design and Development, is Technical Assistant to the Director of Engineering. The Research Department has been expanded in the fields of fluid mechanics, fuels and propellants, mathematics and computers, advanced propulsion studies, nucleonics, and other applied physics. Heading this department is Tibor F. Nagey, Director of Research. His Chief of Preliminary Design is Russell S. Hall. Harvey W. Welch has been named Assistant Chief. Harold D. Wilsted is in charge of Engineering Research, and Robert E. Henderson is head of the Applied Physics Group. John R. Gretzinger has been named Acting Head, Missiles Systems Department. Jack C. Fetters has been appointed Chief Engineer, Turbine Engines; Chester E. Hockert, Assistant Chief Engineer, Turbine Engines; Gordon E. Holbrook, Chief Product Engineer; John B. Wheatley, Chief Design Engineer, Turbine Engines; Jacob C. Schmid, Chief Design Engineer, Fuels and Control Systems; Clair A. Short, Assistant Chief Product Engineer for turbojets; and John M. Wetzler, the same for prop-jets.

• **American Airlines, Inc.,** has announced the election of Walker Lee Cisler to its Board of Directors. Alfred B. Bowman has been named Manager of Flight for the airline's Eastern Region. Norris Shipley, Assistant Vice-President in charge of the Washington, D.C., office, has moved to the company's General Offices in New York to head a new State and Community Affairs Department. Edward K. Rhatigan has been named Director of Ticket Office and Terminal Sales Services. The firm also has announced establishment of a Sales Service Training Division within the Sales Department and has named Roger F. Burkhardt Director.

(*Continued on page 109*)

NAVY'S NEW ATOMIC DEPTH BOMB ANSWERS THREAT OF ENEMY SUBS

THE NEWS THAT "BETTY" is now an operational weapon completes another chapter in the story of the Navy's great contributions to the defense of our country. And we are proud that the Navy Bureau of Ordnance and the Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, developers of this significant weapon, called upon the facilities of AMF for the production of "Betty". This is another demonstration of the fact that, when it comes to the tough jobs, AMF has experience you can use.

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DATELINE world

PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

"The Surface of the Moon" From the Moscow Daily *Izvestiya*

◆ The Scientific Council of the Main Astronomical Observatory has reported the results of the first Soviet attempts to measure temperatures on the surface of the moon. A. V. Markov, Doctor of Physico-Mathematical Sciences, contends that these temperature studies not only determine certain physical conditions of the moon but also contribute to the knowledge of the structure of the moon's surface. The new data show that the temperature changes on the moon range from +120°C. when the sun is at the zenith to −150°C. in the middle of the moon night. The Pulkovo Observatory measures temperatures with a reflecting telescope equipped with a thermoelement and a large radio telescope. Results show that the deeper areas of the moon's surface undergo less temperature change than the higher areas. Investigations prove that the moon's surface shows only slight variation in heat conductivity.

Scientific Center Endorsed for Siberia; Building Begun

◆ The Presidium of the Academy of Sciences of the U.S.S.R. has endorsed a project for a scientific center, covering an area of more than 1,000 hectares, to be built near the city of Novosibirsk in Siberia. It will consist of large research institutes; a university; blocks of flats, schools, hospitals, and clubs; and a stadium.

Construction has already started, and the building which will eventually house the Institute of Hydrodynamics is well under way. When it is finished, it will provide accommodation for a number of other institutes until they are able to move into their own buildings.

Moisture Problem Ended in Japanese Wind Tunnel

◆ Troubled by moisture condensation in a suction-type wind tunnel, the Amagasaki Branch of the Japanese Government Mechanical Laboratory remedied the condition by installing a simple air dryer using approximately one ton of Sovabead (a commercial desiccant of American manufacture).

The difficulty was caused by adiabatic expansion of the air currents and was especially acute during the rainy season. The laboratory reports that, since the air dryer was installed, it has been possible to take schlieren photographs at Mach 1.5 during the summer months.

Perhaps new in Japan, dryers for wind tunnels have been employed in the United States for some time. One such dryer in this country is known to use more than 100 tons of silica-gel as a desiccant.

Letters to the Editor

EDITOR:

While reading the May issue of AERO/SPACE ENGINEERING, I noticed with interest Convair's concept of a nuclear-powered spacecraft.* Something has been bothering me. . . . If this vehicle is intended for interplanetary space flight, then certain basic fallacies appear in the design concept. Since the craft will navigate in open interplanetary space and since according to present theories there exists no friction out there, then laws of economics dictate that there would be no need for acceleration for the duration of the trip between interplanetary bodies except for leaving and landing. A spin imparted to the gondola would be maintained for the nonacceleration portion of the trip with no difficulty, for the ease and comfort of the crew. This would mean that the tow cable between the crew-bearing gondola and the nuclear power plant would have to have a frictionless connection to keep from winding up the cable. How could this be accomplished when the accepted idea of temperatures in outer space approximate absolute zero?

Since this vehicle is intended to travel between planetary bodies and reach a point of no gravity—i.e., a point of balance between the earth's and moon's gravitational attraction—the laws of mutual attraction of masses will hold true:

$$F = k(m_1 m_2 / r^2)$$

where

- F = mutual gravitational attractional force
- k = gravitational constant
- m_1 = mass of nuclear power plant
- m_2 = mass of gondola
- r = distance between the two bodies

Considering the power plant and gondola as two mass particles, this means that they will be mutually attracted, thus allowing the human crew to be subjected to the dangerous radiation poisons emanating from the nuclear power plant. Besides, under these conditions, it is possible—no, likely—that the gondola will wrap its tow cable about the power plant making it impossible to land. This would make it a suicide trip for humans. Out of curiosity, how do the Convair people expect to overcome these problems?

DOMINICK DE BLASIO
28 Sherbrooke Road
Trenton 8, N.J.

AUTHOR'S REPLY: The spin between powered flight phases is imparted not only to the gondola, but to the entire vehicle. . . . Apparently the reader misunderstood and assumes the gondola spins with respect to the cable. In this case, his objections would indeed be justified. But, as the spin is contemplated, no motion of the gondola with respect to the cable occurs.

The spin is not only for passenger convenience, but also to assure that the spring force of the cables does not produce a momentum of the gondola in direction of the nuclear engine after the tension load disappears at cutoff. This cable characteristic, rather than mass attraction, would possibly get the gondola close to the engine and would indeed greatly endanger the crew, even after pile cutoff.

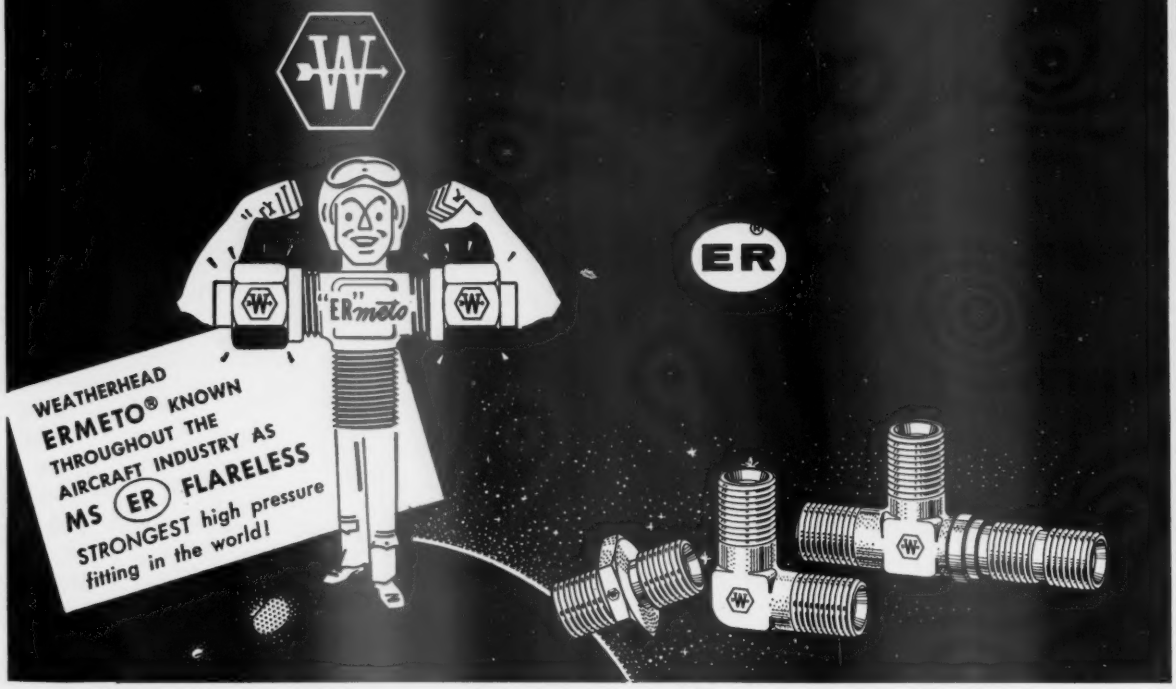
Because the spin of the whole system is like a dumbbell, neither contraction nor wrap-around can occur following cutoff.

K. A. EHRICKE
Assistant to the Technical Director
Convair-Astronautics
A Division of General Dynamics Corp.

* *Our Philosophy of Space Missions*, Krafft A. Ehricke, Vol. 17, No. 5, pp. 38–43.

ATTENTION

all aircraft development and maintenance engineers



The Weatherhead Company has on file many case histories verifying the dependability, low cost installation and maintenance advantages of our famous Ermeto MS flareless hydraulic and pneumatic tube fitting. Perhaps no other fitting has contributed so much to the advancement of aircraft piping technology or has attained wider recognition and usage in critical applications.

We know, however, that there are many types of aircraft installations on which we do not have full technical data. Here's your chance to help us compile a broader range of application information — and maybe win a big cash prize for yourself as well.

This is a national contest open to all design, planning and maintenance men with a story to tell on either the Weatherhead Ermeto tube fitting in industrial applications, or the MS flareless fitting in aircraft.

1st Prize . . . $1500.00
2nd Prize . . . $1000.00
Next 8 Winners $750.00
175 Other Cash Prizes

act now . . . contest closes Sept. 30, 1958

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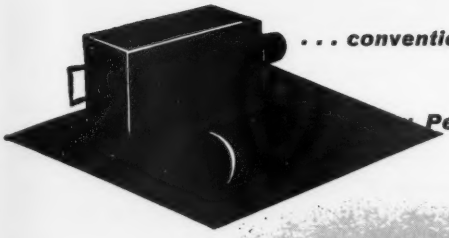
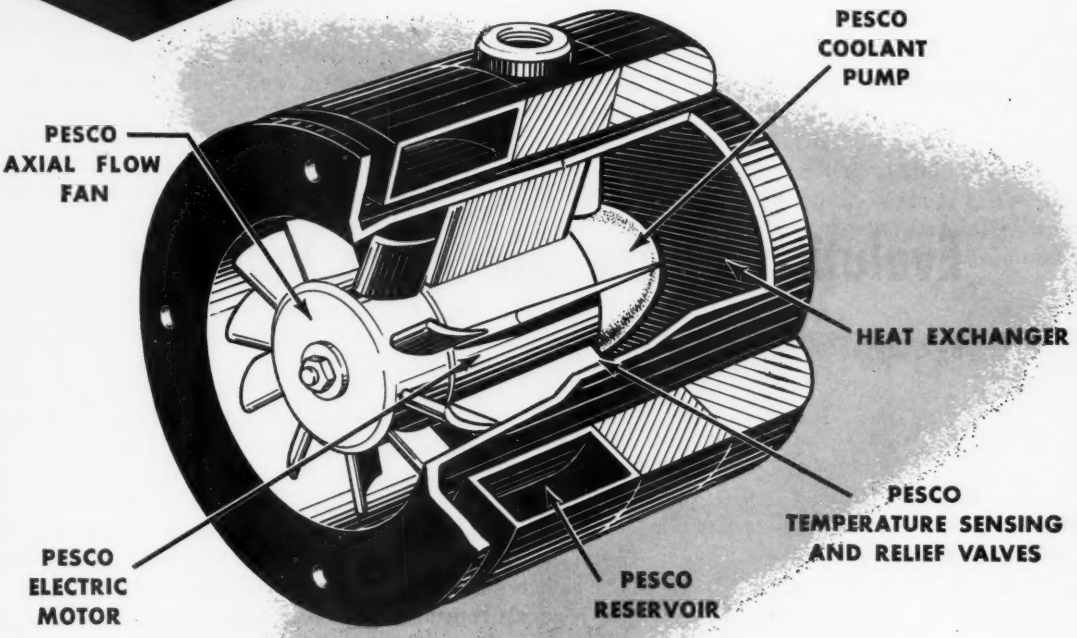


. . . conventional cooling unit is bulky, heavy, complicated.

. . . Pesco Cooling Package is lighter, smaller, simpler.



Pesco electronic cooling packages . . .

integral, miniaturized design saves space and weight

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GUEST EDITORIAL

Evolution of the Air-Space Industry

By General Orval R. Cook, USAF (Ret.)

Within the great circle of debate over our national defense program, there are substantial areas where misinformation and lack of information are creating wholly erroneous impressions in the public mind.

This is particularly true in our missile program and its allied space program. There has been a floodtide of publicity in the past year regarding missiles, with emphasis on the intercontinental ballistic missiles. The ICBM was termed the "ultimate weapon"; no defense was possible, some pseudoexperts stated. The manned aircraft was relegated to the ash heap of our defense program by this group.

Then the satellite launchings brought another school of defense thought into full play, and the ICBM, even before it became operational, was looked upon as just another weapon.

This helter-skelter approach is further compounded by statements that a new missile-space industry has suddenly emerged to design, develop, and produce missiles and space vehicles.

The theory of the missile as a power weapon has been known since rockets were employed by the Chinese against the Tartars in the 13th Century. They were used by the British Rocket Corps in the 18th Century with notable success. The first powered flight made by the Wright Brothers in 1903 added significantly to the meager storehouse of aeronautical knowledge. Dr. Robert H. Goddard's experiments in firing scores of high-altitude rockets in the 1920's and 1930's were another milestone. During World War II, guided bombs (or missiles) utilizing remote control techniques were tested on an operational basis. The firing of V-2 missiles by the Germans against England in the late days of World War II brought their employment into sharper military focus.

However, a factual assessment of these events and numerous other contributing events shows that no single occurrence can logically claim to be the originating point of missiles. The present crop of missiles grew from a combination of all these aerodynamic efforts, of fuel and metallurgical research, and the amazing progress of electronics—the fastest growing segment of the industry. Each successive improvement in design, development, and production of missiles has drawn upon the reservoir of knowledge and experience acquired by the aircraft industry which, incidentally, was engaged in research and development of missiles, including the ICBM and IRBM types,

nearly 15 years before these initials became so well known to the public.

The prime job of getting into space, performing a mission, and returning to earth is simply an extension of long-extant aviation principles. Basically, the power plants, the airframe, and the guidance are refinements and extensions of today's manned aircraft. Our first man in space probably will go there in an airplane. The lunar probes recently ordered by the Defense Department will use rocket engines similar to those that power the current models of ICBM's and IRBM's. And these engines were designed, developed, and produced by a company that has built more aircraft than any other manufacturer.

One of the most advanced projects now under way is the Dyna-Soar, a spacecraft that is a combination of a manned aircraft and missile, utilizing both centrifugal force and aerodynamic lift in a boost-glide effect from the very high layers of atmosphere. Development contracts have been awarded to teams of aircraft manufacturers. Dyna-Soar is only one of several imaginative projects for space exploration that have been offered by the aircraft industry in its efforts to keep this nation predominant in all phases of aviation from two-place personal aircraft to the sophisticated space systems.

William M. Holaday, Director of Guided Missiles for the Department of Defense, in testimony before a Senate Committee, recently stated:

"Now, in the question of missiles, we are not only talking about ballistic missiles but also about aerodynamic missiles and decoys....The first consideration, I would say, is to put the business into that area where the specialists are. In nearly all cases, this turns out to be people in the aviation industry. They have the know-how to make weapon systems. They have the engineers, and they are capable. So, I would say that, in general, this has been the direction in which we have moved—that is, back to the aviation industry."

Mr. Holaday's comments on know-how and capability of the aviation industry have a solid basis. The technical force the aircraft industry is able to bring upon a missile program is unequalled by any other manufacturing industry. For example, an aircraft company charged with prime responsibility for an air defense missile system assigned 3,800 engineers to work directly on the various facets of the program. The company is utilizing 700 engineers for the flight-test phase alone. A force of 600 engineers is needed to carry out technical liaison with subcontractors and for base construction planning and surveillance.

Statements that missiles and spacecraft are totally "new" and that the manufacturing experience acquired by the aviation industry in conventional aircraft cannot be applied are completely irresponsible. This irresponsibility has been carried to a point where aeronautics and astronautics are claimed to be completely separate, sharply divided at some undisclosed point. Astronautics is a logical progression stemming from aeronautics. It is completely possible that the astronautics extension may someday overshadow its aeronautics foundation. However, the two can no more be divorced than can the industry building aircraft, missiles, and spacecraft be separated.

There is no question that efficient production of missiles and space systems has brought about new methods, techniques, and engineering concepts, roughly comparable to the changes that occurred as aircraft passed from wood and fabric to all-metal planes and the advance from piston-powered planes to supersonic turbojet planes.

But change is the only constant in an industry governed by a dynamic technology. The industry that brought aircraft to their advanced state is the same industry that is vigorously moving forward with the vehicles that will carry man into the great adventures in space.

General Cook is President, Aircraft Industries Association of America, Inc. Immediately prior to retirement in May, 1956, after 38 years in military service, he was Deputy Commander in Chief, United States European Command. From July, 1951, until assignment in February, 1954, to the European Command, he served as the USAF'S Deputy Chief of Staff for Materiel at Air Force Headquarters in Washington. He has been awarded the Distinguished Service Medal and Legion of Merit.

Eleanor L. Semple and William C. Cooley
General Electric Company

Direct Cycle Nuclear Turbojet Power Plants

"This analysis of direct cycle nuclear turbojets shows that two of the most significant factors affecting the power-plant thrust/weight ratio and, therefore, the aircraft capabilities are the turbine inlet temperature and the reactor free flow fraction."

Since 1951, the General Electric Company has conducted a research and development program for the USAF and the Atomic Energy Commission leading toward the evolution of militarily useful nuclear aircraft power plants. Primary efforts have been concentrated on the development of direct cycle nuclear turbojets rather than closed cycles, which would employ a secondary fluid and a heat exchanger to transfer energy to the air. In the direct cycle power plant, a nuclear reactor replaces the combustion chamber of a conventional turbojet engine. Air is ducted from the compressor directly through the reactor where heat is generated by fission within the reactor fuel elements and is transferred by conduction and forced convection to the compressed air before the air enters the turbine.

Without discussing specific materials or designs under consideration by the General Electric Aircraft Nuclear Propulsion Department, it is possible to estimate the effects of the more important design parameters on the flight performance of direct cycle nuclear turbojet power plants and to outline some of the characteristics of this type of power plant.

Power-Plant Performance Requirements

The range of conventional turbojet-powered aircraft is limited by the fuel capacity. The weight of fuel (fissionable material) consumed in a nuclear power plant is negligible; but for the nuclear-powered aircraft, a radiation shield is required which is adequate to protect the crew from neutrons and gamma rays generated in the nuclear reactor. A nuclear-powered aircraft has an essentially constant gross weight, whereas the gross weight of the chemically fueled aircraft decreases as fuel is consumed.

Miss Semple is Technical Engineer in the Aircraft Nuclear Propulsion Department. Dr. Cooley was Manager, Systems Analysis, Aircraft Nuclear Propulsion Department of G-E; now he is Assistant Program Engineer—Rover Project, Rocketdyne, a Division of North American Aviation, Inc.

At cruise conditions, the thrust developed by the power plant (F_c) must equal the drag of the aircraft (D), and the lift (L) must equal the aircraft gross weight (W_g). An estimate of nuclear power-plant thrusts and weights required for an aircraft is obtained from the following simple analysis. The nuclear aircraft gross weight is assumed to consist of three components:

$$W_g = W_u + W_{st} + W_n$$

where

W_u = useful load, including payload, fixed equipment, and crew
W_{st} = airframe structural weight
W_n = total weight of nuclear power-plant components, including all radiation shielding.

Assuming that the airframe structural weight is a constant fraction (α) of the gross weight and substituting the lift/drag ratio (L/D) for the ratio of gross weight to cruise thrust, the following equation may be written:

$$W_g = \frac{W_u}{(1-\alpha) - [1/(L/D)\,(F_c/W_n)]}$$

where (F_c/W_n) is the thrust/weight ratio of the nuclear power plant. This equation is plotted in Fig. 1 to show the aircraft gross weight required as a function of power-plant thrust/weight ratio for various values of useful load. It is assumed that the airframe structure weighs 25 per cent of the gross weight, and the lift/drag ratio is 15 to correspond to a typical subsonic airframe configuration. A scale for required cruise thrust also is shown in Fig. 1, the cruise thrust being equal to the gross weight divided by the lift/drag ratio. It may be noted that the gross weight is proportional to the useful load for any fixed power-plant thrust/weight ratio. For a specified useful load and maximum allowable gross weight, the required thrust may be read from the right-hand ordinate of Fig. 1 and the required thrust/weight ratio (F_c/W_n) from the abscissa scale. As an

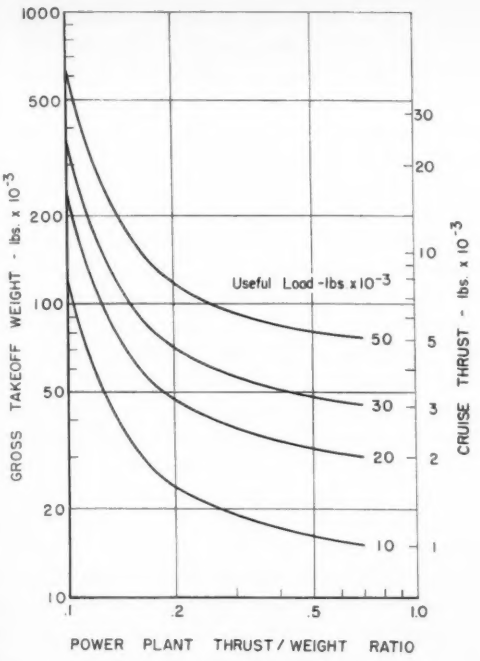

FIG. 1. Aircraft performance.

illustration, for a useful load of 50,000 lbs. and a gross weight of 300,000 lbs., the required cruise thrust is 20,000 lbs. and the power-plant thrust/weight ratio must be at least 0.114. Therefore the nuclear power plant can weigh no more than:

$$20{,}000/0.114 = 175{,}000 \text{ lbs.}$$

Fig. 1 also demonstrates that the thrust/weight ratio for the power plant should be as high as possible to minimize the gross weight of the aircraft required to carry a specific useful load.

POWER-PLANT THRUST

The factors affecting power-plant thrust will be considered first. The total net cruise thrust (F_c) of a turbojet power plant is given by the product of the specific net thrust obtained by cycle analysis (I_{sp}) and total mass flow rate of air (W_a).

The magnitude of specific thrust is a function of the flight Mach Number and altitude, the compressor pressure ratio, the pressure drop from compressor discharge to turbine inlet, the turbine inlet temperature, and the component efficiencies. Fig. 2 shows typical values of specific thrust for a turbojet engine at an assumed flight condition of 0.7 Mach Number and 35,000-ft. altitude plotted as a function of the compressor pressure ratio and the turbine inlet temperature for fixed values of the other independent variables. These curves indicate the significant increases in specific thrust attainable by increasing the turbine inlet temperature, and they show that there is an optimum compressor pressure ratio for each turbine inlet temperature. For the nuclear power plant, an increase in turbine inlet temperature implies an increase in the reactor discharge temperature, which requires higher operating temperatures for the reactor fuel elements.

Fig. 3 shows the effect on specific thrust of the pressure drop through the reactor and shield ducting system between compressor discharge and turbine inlet. This curve is drawn for a representative compressor pressure ratio and turbine inlet temperature; the shape of the curve will remain the same for other compressor pressure ratios and turbine inlet temperatures. It is clearly advantageous from the standpoint of cycle performance to minimize pressure losses in the ducting and reactor heat-transfer system.

In summary, the major factors contributing to a high specific thrust are a high turbine inlet temperature and a low pressure drop in the reactor heat-transfer system. The airflow through a turbojet engine decreases with increasing altitude until the thrust becomes too low to sustain level flight. To overcome this limitation, more or larger jet engines may be used. This increases the airflow capacity of the power plant, thereby increasing the total thrust.

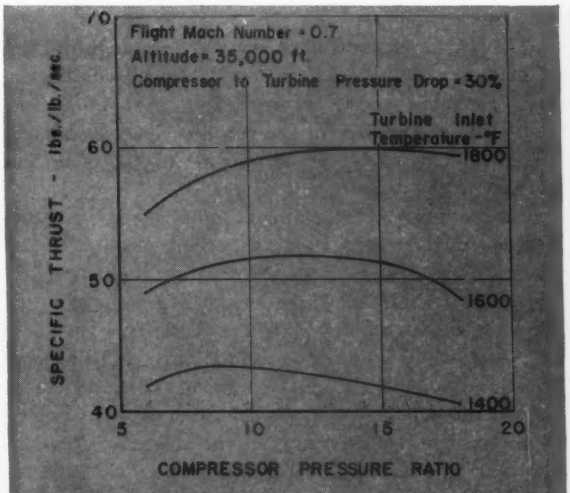

FIG. 2. Specific thrust versus compressor pressure ratio.

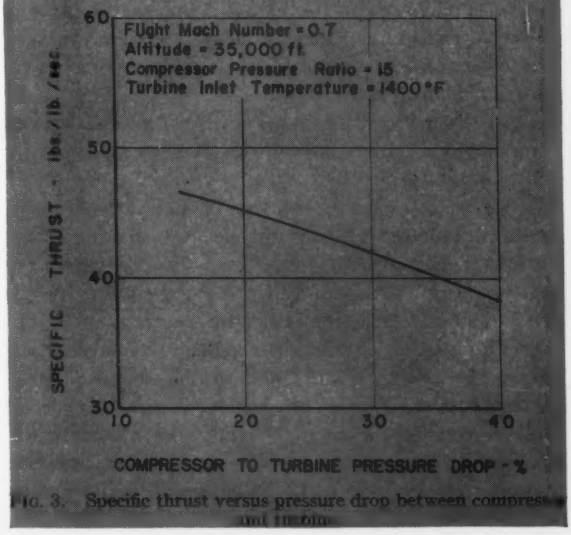
Flight Mach Number = 0.7
Altitude = 35,000 ft.
Compressor Pressure Ratio = 15
Turbine Inlet Temperature = 1400 °F
SPECIFIC THRUST - lbs / lb / sec
COMPRESSOR TO TURBINE PRESSURE DROP - %

FIG. 3. Specific thrust versus pressure drop between compressor and turbine.

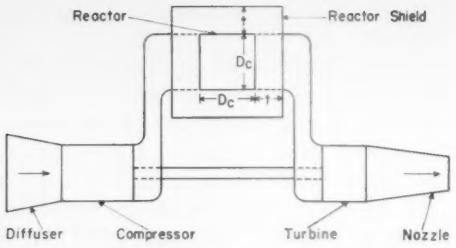

FIG. 4. Schematic drawing of nuclear turbojet power plant.

POWER-PLANT WEIGHT

In order to estimate the thrust/weight ratio attainable with the nuclear turbojet, it is necessary to investigate next the power-plant weight.

To facilitate the analysis, a nuclear turbojet power plant with the simplified configuration shown in Fig. 4 is selected. The turbomachinery is of conventional design with an arbitrary airflow capacity; air is ducted from the compressor discharge through a radiation shield, through a reactor, out through the shield, and into the turbine.

The reactor is assumed to be a right circular cylinder, of diameter (D_c) equal to its length, composed of a material having a specific gravity of 2.0. A free flow fraction (R_{ff}) is specified for the reactor which determines the airflow area, $A_{ff} = (R_{ff})\ (\pi/4)\ (D_c^2)$, for airflow parallel to the axis of the reactor.

For simplicity, all shielding is assumed to be a homogeneous mixture with a mean specific gravity of 2.0. The mixture consists of a light neutron shielding material, such as borated water, and a heavy gamma ray shielding material, such as lead. A uniform thickness (t) is used on all sides of the reactor core. For purposes of estimating shield weight, the shield is assumed to be solid because reductions of shield average density due to the presence of air ducts in the region of the core inlet and discharge must be compensated by a corresponding increase in shield thickness. The important factors which establish the required shield thickness are: the reactor power level, the radiation tolerance of the crew, the amount of local shielding around the crew, and the limits on radiation damage or neutron activation of the airframe.

Since the allowable radiation level for the airframe components usually is considerably higher than that for the crew, it is possible to employ the divided shield concept. In general, there is an optimum division between the reactor shielding and the crew shielding which leads to a minimum total shield weight.[1] At one end of the spectrum, all shielding is around the crew; at the other end, a unit shield around the reactor is used. In this analysis, the minimum permissible thickness of the reactor shield (t) is assumed to be that which allows a maximum dose rate for the airframe components of 10^5 rem/hr. of either neutrons or gamma rays by attenuation through the shield material and through an assumed separation distance of 50 ft. The shield weight associated with this minimum thickness is slightly higher in each case than the optimum reactor shield weight; so that, for the conditions imposed on the study, the minimum total shield weight is determined by the minimum reactor shield thickness. The crew compartment is assumed to be a 6-ft. diameter by a 6-ft. long cylinder allowing a little more than 75 ft.^{3}/man for each of the two-man crew. The crew shield required in addition to the reactor shield is composed of three parts. The rear part, which shields against direct radiation, has a 6-ft. diameter and a thickness (t'). This thickness is established by an assumed maximum allowable dose rate for the crew of 0.5 rem/hr. for combined neutron and gamma radiation at the separation distance of 50 ft. The second part of the crew shield, with thickness equal to $1/3\ t'$, is wrapped around the cylindrical crew compartment; the third part, also with thickness equal to $1/3\ t'$, covers the front of the crew compartment. The latter two parts of the crew shield are assumed to be adequate to protect against all radiation scattering effects.

The turbojet engine weight is calculated by scaling one version of the General Electric J-47 engine, which has a weight of 2,700 lbs. and a sea-level static airflow of 90 lbs./sec. The weight of larger engines is assumed to be proportional to the 3/2 power of the sea-level static airflow rate and to be independent of the compressor pressure ratio. The additional weight of ducting to and from the reactor associated with the nuclear turbojet engine is assumed to be partially offset by the eliminated weight of the conventional chemical combustion system included in weights scaled from the J-47 engine. In any case, these duct weights are small compared to the reactor and shield weights and are neglected.

Using the assumptions stated above, the total weight of the nuclear power plant may be computed from the

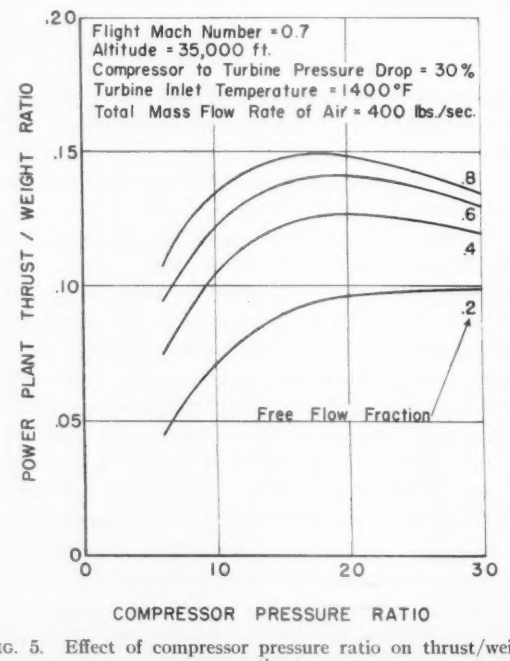

FIG. 5. Effect of compressor pressure ratio on thrust/weight ratio.

following relationships:

$$W_n = W_e + W_r + W_{rs} + W_{cs}$$

where

$W_e = 3.16\,(W_a)^{1.5}$ = weight of turbomachinery, lbs.

$W_r = (1-R_{ff})\,[(\pi/4)D_c^3]\,(2.0)\,(62.4)$ = weight of reactor, lbs.

$W_{rs} = (\pi/4)\,[(D_c + 2t')^3 - D_c^3]\,(2.0)\,(62.4)$ = weight of reactor shield, lbs.

$W_{cs} = \big((\pi/4)\,(6)^2\,(t') + (\pi/4)\,(6)^2\,(t'/3) + (\pi/4)\,(6)\,\{[6 + (2/3)\,t']^2 - (6)^2\}\big)\,(2.0)\,(62.4)$ = weight of crew shield, lbs.

With the exception of engine weight, the power-plant weight is a function of reactor geometry alone.

Engine Cycle - Reactor Geometry Relationship

A relationship between engine thermodynamic cycle and the core diameter of the reactor must be found in order to find the power-plant weight which corresponds to the cruise thrust of a particular engine. This relationship is determined by considering the heat-transfer characteristics of the reactor core.

For specific thermodynamic cycle conditions, the design conditions for the reactor consist of the inlet and outlet pressures, the inlet and outlet temperatures, and the air mass flow rate. The required reactor frontal area is given by:

$$A_{fr} = (\pi/4)D_c^2 = W_a/G\,R_{ff}$$

where W_a is the air mass flow rate, R_{ff} is the reactor free flow fraction, and G is the mass velocity (lbs./ft.^{2} sec.) which can be passed through the reactor with specified temperature rise and pressure drop. In order to minimize reactor size and therefore minimize shield weight, the product GR_{ff} should be as high as possible.

The permissible free flow fraction is determined primarily by the volume of solid material (moderator, nuclear fuel, structure, and controls)which is required to meet the nuclear and mechanical design requirements. The parameter, R_{ff}, will be retained as an important independent variable.

The allowable mass velocity, G, is a function of the reactor heat-transfer surface temperatures and of the heat-transfer and friction characteristics of the heat-transfer passages.

The allowable mass velocity is derived by making the following simplifying assumptions:

(1) The air passages have a uniform hydraulic diameter, D_h.

(2) The modified Reynolds analogy[2] applies to relate heat transfer (Stanton Number) to the friction coefficient, f:

$$h/C_pG = \lambda\,(f/2)$$

where $\lambda = 0.70$ is assumed for rough passages.

(3) The air Mach Numbers are low subsonic so that no distinction need be made between total and static pressures or temperatures and so that acceleration pressure drop may be neglected relative to friction pressure drop.

(4) The Fanning friction factor is given by $f = 0.0814\,(D_hG/\mu)^{-0.2}$ which is 77 per cent higher than for smooth tubes.

(5) The reactor heat-transfer surface temperature (T_w) is maintained uniform and equal to 2,000°F.

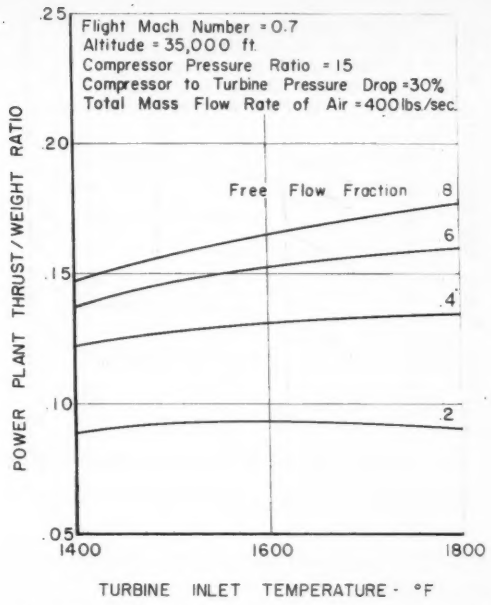

Fig. 6. Effect of turbine inlet temperature on thrust/weight ratio.

By combining the equations for energy, heat transfer, pressure drop, and the perfect gas law, it may be shown that the allowable mass velocity through the reactor flow passages is:

$$G = \sqrt{\frac{\lambda g}{R}\,\frac{P_a}{T_a}\,\frac{P_{in} - P_{out}}{\ln\,[(T_w - T_{in})/(T_w - T_{out})]}}$$

where P_a and T_a are the average air pressures and temperatures, $g = 32.2$ ft./sec.^{2}, and R is the gas constant for air (53.35 ft.-lb./lb. °F.). It is seen that the allowable value of G increases with increasing average air pressure, pressure drop, and wall temperature.

In the numerical calculations, it was assumed that there is a 5 per cent pressure drop between compressor exit and reactor inlet and 5 per cent between reactor outlet and turbine inlet. The reactor design pressure drop was varied from 5 per cent to 30 per cent to show that there is an optimum value.

Using the above methods to obtain core size for any operating point, the nuclear power-plant thrust/weight ratio can be determined as a function of the following independent variables: the thermodynamic cycle, W_a, and R_{ff}.

The independent variables upon which the thermodynamic cycle depends were narrowed to the compressor pressure ratio, the turbine inlet temperature, and the compressor to turbine pressure drop by considering

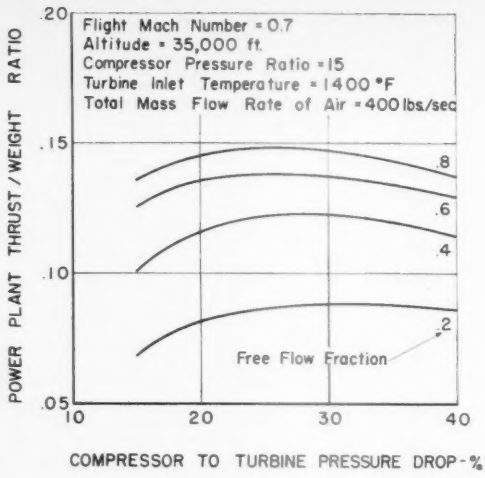

FIG. 7. Effect of pressure drop on thrust/weight ratio.

a single flight condition and holding constant the component efficiencies.

Up to this point, the internal geometry of the reactor core has been ignored since the power-plant thrust/weight ratio may be computed independently of it. However, it is of interest to note that the modified Reynolds analogy on which the heat-transfer requirements are based provides, also, a relationship between the length of the active reactor core and the hydraulic diameter (D_h) of the air passages assumed in this analysis as follows:

$$L_c/D_h^{1.2} = 8.95 \ln [(T_w - T_{in})/(T_w - T_{out})] (G/\mu)^{0.2}$$

where L_c = length of active reactor, ft., and μ = viscosity of air at mean temperature, lbs./sec. ft.

The hydraulic diameter determined from this equation for a particular design point can be used in conjunction with the corresponding reactor core diameter and free flow fraction to determine the feasibility of the design from the standpoint of nuclear and structural considerations. No attempt has been made to incorporate this consideration into the analysis.

RESULTS

The following series of graphs shows the effect on power-plant thrust/weight ratio of each of the independent variables required to compute the thrust/weight ratio.

Fig. 5 presents the effect of compressor pressure ratio on the power-plant thrust/weight ratio. The graph is drawn for fixed values of turbine inlet temperature, airflow, and compressor to turbine pressure drop, and for a range of reactor free flow fractions. As compressor pressure ratio increases, the density of air entering the reactor increases, thus permitting a lower free flow area for the same mass flow rate of air. The resulting decrease in reactor core diameter for any fixed free flow fraction produces a significant decrease in power-plant weight. Fig. 2 shows the optimum compressor pressure ratio with respect to specific impulse for the same turbine inlet temperature and compressor to turbine pressure drop used in Fig. 5. By comparing the two plots, it may be seen that the optimum compressor pressure ratio with respect to thrust/weight ratio has a considerably higher value because of the power-plant weight effect. The same weight effect is demonstrated in the increase of thrust/weight ratio with increasing free flow fraction at a fixed compressor pressure ratio; higher free flow fractions imply smaller reactor core diameters at the same thermodynamic cycle point.

Since the optimum compressor pressure ratios are far higher than those attainable with conventional turbomachinery, a compressor pressure ratio of 15 is arbitrarily assumed for the remainder of the study.

In Fig. 6, the effect of turbine inlet temperature on power-plant thrust/weight ratio is shown for a fixed compressor pressure ratio, airflow, and compressor to turbine pressure drop, and for varying values of reactor free flow fraction. Fig. 2 shows the significant increases in specific thrust attainable by increasing the turbine inlet temperature. It is to be noted in comparing Figs. 6 and 2 that this decided improvement in engine performance is counterbalanced by the power-plant weight considerations and, indeed, is negated at low values of free flow fraction where the reactor core diameter increases rapidly in order to provide the heat-transfer surface necessary to accomplish higher turbine inlet temperatures. This result is dependent on the assumption of a constant reactor wall temperature of 2,000°F., despite variations in turbine inlet temperature.

The effect on power-plant thrust/weight ratio of the pressure drop between compressor discharge and turbine inlet is presented in Fig. 7 for the same representative compressor pressure ratio and turbine inlet temperature used in Fig. 3. It was mentioned previously, in discussing Fig. 3, that the specific impulse of the turbojet engine is continuously improved by decreasing the pressure drop between compressor discharge and turbine inlet. However, Fig. 7 demonstrates that this improvement does not extend to the thrust/weight

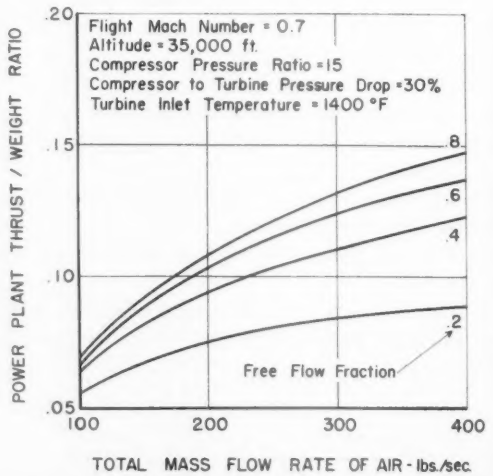

FIG. 8. Effect of power-plant design airflow rate on thrust/weight ratio.

ratio and that there is an optimum pressure drop of about 30 per cent for any free flow fraction, beyond which the thrust/weight ratio drops off quite rapidly. The effect is caused by the larger core diameters required to pass the airflow at the low values of reactor pressure drop, with their consequent heavier reactor shielding and higher power-plant weight. As in Figs. 5 and 6, Fig. 7 also shows the increase in power-plant thrust/weight ratio to be expected with increasing reactor free flow fraction.

The effect of engine size or airflow on thrust/weight ratio for a fixed thermodynamic cycle point is shown in Fig. 8. Engine thrust varies directly with engine airflow, as do the engine and reactor flow areas. The crew shield weight is assumed constant, so that total power-plant weight increases less rapidly than total thrust as engine size is increased. In other words, the thrust/-weight ratio increases as the design airflow is increased. The effect is most noticeable at high free flow fractions where the reactor core diameters are relatively small, and crew shield weight is a greater percentage of the total power-plant weight. An engine airflow of 400 lbs./sec. at the design Mach Number and altitude has been arbitrarily chosen for evaluating the power-plant design.

In Fig. 9, performance of the power plant is presented in terms of aircraft gross take-off weight and useful load as a function of the turbine inlet temperature and reactor free flow fraction. All other independent variables have been fixed by optimization or arbitrarily selected. For the example originally cited—i.e., a 300,000 lb. aircraft carrying a 50,000 lb. useful load—Fig. 9 shows that a turbine inlet temperature of about 1,560°F. and a free flow fraction of about 0.3 will satisfy the requirements. To increase the useful load

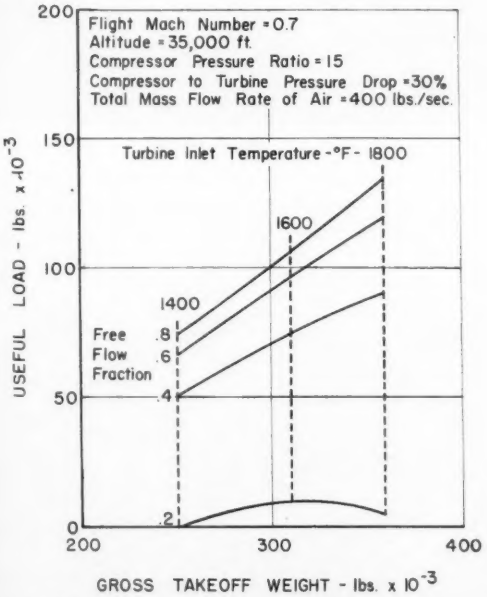

FIG. 9. Useful load versus aircraft gross weight for a fixed power-plant airflow rate.

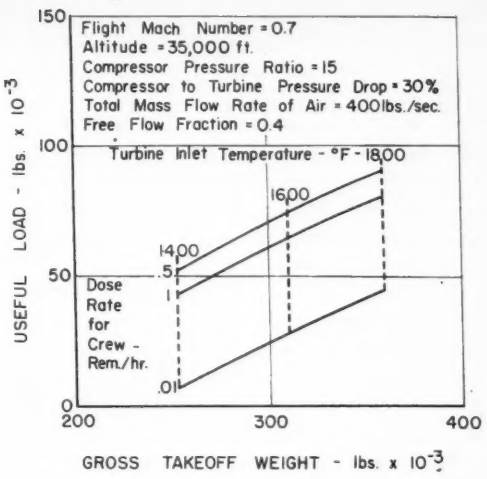

FIG. 10. Effect of crew dose rate on useful load.

for the same aircraft gross weight, the reactor must be designed with a higher free flow fraction for the same turbine inlet temperature. However, it is possible to increase the useful load by increasing the gross take-off weight and operating the power plant at a higher turbine inlet temperature with the same free flow fraction in the reactor.

Aircraft useful load is affected radically by changes in allowable radiation dose levels. Fig. 10 shows the effect on useful load of varying the maximum allowable dose rate for the crew while keeping fixed the allowable radiation level for the airframe components, thus affecting only the weight of the crew shielding. Useful load is plotted against gross take-off weight for several crew dose rates using the same cycle assumptions as in Fig. 9 with an arbitrarily selected free flow fraction of 0.4.

CONCLUSIONS

This analysis of direct cycle nuclear turbojets shows that two of the most significant factors affecting the power-plant thrust/weight ratio and, therefore, the aircraft capabilities are the turbine inlet temperature and the reactor free flow fraction. Both of these parameters should be as high as possible to obtain the maximum thrust/weight ratio. However, increasing these factors presents very difficult problems involving selection of reactor materials and mechanical, thermal, and nuclear design of the reactor core. The most significant improvements in power-plant performance will be based on the attainment of higher reactor discharge temperatures and/or decreases in reactor core volume per unit of airflow rate.

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[2] McAdams, William H., *Heat Transmission*, 3rd Ed., pp. 155, 162, 210, 219; McGraw-Hill Book Company, Inc., N.Y., 1954.

The main purpose of this paper is to cover a method of physical simulation and equipment evaluation through the use of a complete three-dimensional flight simulator facility.

Three Axis Flight Simulator Systems

Wallace E. Gibson
Bendix Aviation Corporation

THE TERM "flight simulator" has an interesting connotation. Its mention causes a variety of mental pictures to cross the minds of both technical and nontechnical personnel. One of the earlier and more generally known usages was to simulate vehicle motion (such as an aircraft or submarine) for the purpose of training operational personnel.

With the emphasis in the past few years on the development of unmanned air vehicles, as well as the problem of controlling supersonic manned aircraft, it has become quite apparent that an accurate method of "checkout" for both individual components as well as complete control or guidance systems is of paramount importance.

An analog computer has been found to be an extremely useful tool in the solving of aircraft flight equations. If it can operate on a 1:1 time scale, portions of the system can be included in the test without mathematical simulation. For example, an adequately designed flight simulator is a flexible 1:1 time scale computer that simulates aircraft parameter changes so that literally thousands of "test flights" may be made under controlled laboratory conditions. Such simulation permits one to test the behavior of a new subsystem or complete system.

The author is Project Administrator of the Control Systems Group, Bendix Computer Division.

Many persons were involved in the design, development, and assembly of the Bendix Flight Simulator equipment discussed in this paper. Special recognition is due, however, to the Bendix Research Laboratories Division, Detroit, Mich., for their engineering foresight, ingenuity, and ability. Its successful culmination was due in a large measure to the engineering staff working under the direction of Charles M. Edwards and Murray Kanes.

FIG. 1. Flight Table.

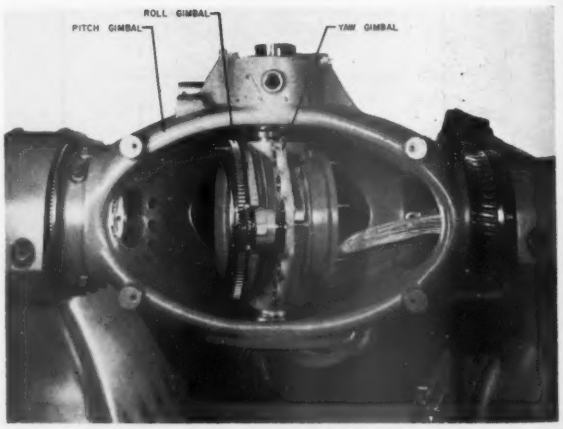


FIG. 2. Flight Table gimbals (side view yaw and roll).

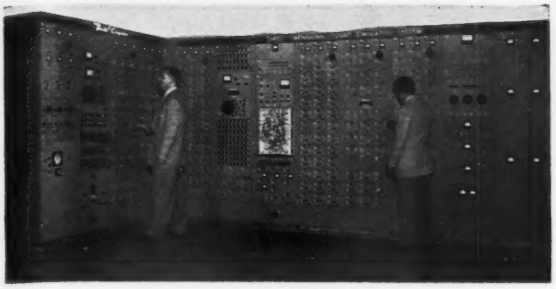


FIG. 3. Computer.

STUDIES OF AIRCRAFT RESPONSE TO CONTROL

The linearized flight equations are frequently used for analyzing the response of different airframe configurations to the control surface motions. This can be done quite readily by evaluating the transient behavior of the aircraft after a given surface deflection. The computer may be set up to solve the linearized flight equations associated with the transient or frequency variant response of the aircraft. The input disturbances may be either step or sinusoidal of varying frequencies. It should be noted that the above type solutions pertain to a system analysis and synthesis. This type of evaluation normally uses a closed loop on computing elements found in an analog computing system.

It is universally agreed that without the use of computers in system analysis and synthesis the engineer or scientist would still be groping for answers to aerodynamics, stability, and many other problems that are paramount to man's knowledge if he is to satisfactorily conquer space flight. After a control or guidance system is analyzed, designed, and assembled, it must go through a severe checkout period. It becomes apparent, then, that some means of physically checking such components or systems prior to flight testing is highly desirable. The use of such a system reduces the risks of expensive abortive flights.

The main purpose of this paper, therefore, is to cover a method of "physical simulation" and "equipment evaluation" through the use of a complete three-dimensional flight simulator facility. The equipment specifically referred to was designed by the Bendix Aviation Corporation, Research Laboratory Division, Detroit, Mich., and is currently being fabricated by the Bendix Computer Division, Los Angeles, Calif. Four complete systems are now in use and a fifth is presently being assembled. This system consists of two major components:

(1) The Flight Table (shown in Fig. 1) consists of three dynamic elements permitting the three motions of flight (pitch, roll, and yaw). The gimbals (Fig. 2) supported by a massive vibration absorbing base are designed to permit continuous gimbal rotation in all three planes.

(a) Pitch Gimbal—The pitch, or outer gimbal, defined as the "Y" axis, is an ellipsoid-shaped structure utilizing the "Al-Fin" aluminum casting process. Steel bearing inserts are bonded into the casting as an integral part. (Bond strength: 15,000 psi; tension: 7,000 psi shear.)

The pitch gimbal is the largest of the dynamic structural elements. Its torsional spring rate is approximately 174×10^6 lb.-in./rad. The unloaded moment of inertia is approximately 11 lb.-in.-sec.^{2}. The net inertia of the entire unloaded gimbal structure is 58 lb.-in.-sec.^{2}. This includes all three gimbals with the associated gears, motors, instruments, slip ring assemblies, etc.

A honeycomb sandwich type structure was considered in the early design as a means of keeping the mass to a minimum and the stiffness to a maximum. Several design configurations were completed up to the prototype stage. The torsional stiffness of the cast gimbal, however, was found to be 175 per cent greater than that of the fabricated sandwich construction type. The new increase in the total pitch inertia, by adopting a casting construction, was only 7.72 per cent with an increase in weight of about 15 per cent.

(b) Yaw Gimbal—The yaw, or middle gimbal, defined as the "Z" axis, supports the roll gear and bearing to which the pay load is mounted.

The yaw gimbal is also designed for maximum stiffness, using the "Al-Fin" aluminum casting process. The measured torsional spring rate is 125×10^6 in.-lb./rad. The unloaded moment of inertia is 8.6 lb.-in.-sec.^{2}. The yaw gimbal provides an 8-in. diameter internal mounting area, open on both sides.

(c) Roll Gimbal—The roll gimbal, defined as the "X" axis, consists of an integral roll gear and bearing. This unit combines a precision zero-backlash gear with a preloaded precision bearing. The maximum static capacity of the bearing in the plane of the contact angle is approximately 20,000 lbs. This is equivalent to subjecting a 300-lb. load with a c.g. 20 in. from the yaw axis to a linear acceleration of 10g's.

(d) Instruments—Each axis is equipped with five a.c. resolvers, one tachometer, and a linear potentiometer. The yaw gimbal instrument group also includes a secant potentiometer used in computing Euler angle transformations.

(2) The computer (Fig. 3) contains the necessary electronics to properly control the Flight Table in all modes of operation. Specifically it contains the following:

(a) Eighty-eight d.c. amplifiers (20 of which can be used as integrators).

(b) Five electronic multipliers of the time division type capable of performing the multiplication of a primary variable by one to four secondary variables for a total of 15 products.

(c) A.c. computing equipment associated with twelve resolver chains for vector resolutions.

(d) Servocontrol section to control each of the gimbal axes.

(e) Built-in power supplies including reference amplifiers and oscillators.

(f) Necessary control panel areas including prepatch problem boards and all monitoring equipment such as oscilloscopes, VTVM's, digital voltmeters, etc. (A complete set of system and component specifications will be supplied by the author upon request.)

The equipment was originally developed under a Navy contract to provide this important link between system synthesis and the actual flight testing of fast air-to-air missiles, on a real time base.

Servovalve

Perhaps the major design problem was to develop an extremely high performance servovalve system capable of driving a 0.6 lb.-in.-sec.^{2} payload inertia at speeds up to 50 rad./sec. and at maximum accelerations in the order of 2,500 rad./sec.^{2}. The bandpass requirements of the system had to be over 100 cps. The servo also had to exhibit excellent low-speed - low-frequency characteristics and operate within a speed variation of less than $^1/_2$ per cent at speeds as low as 0.3 rad./sec. (The principal factor that limited the low-speed performance was the a.c. tachometer.) The key to the successful culmination of this high-performance hydraulic rate servo was due to the design and development of the high-performance, high-power (50 hp.) valve. The design incorporated a single spool pilot valve, torque motor, power valve, velocity feedback transducer, and position feedback linearsyn transformer assembled in a compact package and mounted directly to the body of the hydraulic motor. The initial design specifications of 500 cps natural frequency with a phase shift of not more than 10° at 100 cps was achieved.

Servovalve Loop

The associated servosystem that has been developed comprises a multiloop system including an integrally designed two-stage hydraulic servovalve, a 30 hp. hydraulic motor, electronic amplifiers, and transducers. The block diagram of the servosystem and flow valve loop are shown in Fig. 4.

What this means, therefore, is that the Table, added

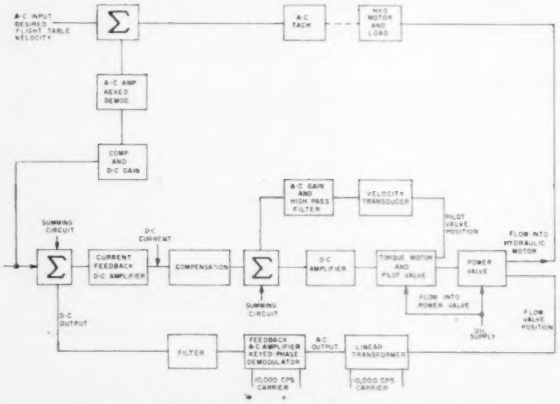


Fig. 4. Block diagram Flight Table servoloop.

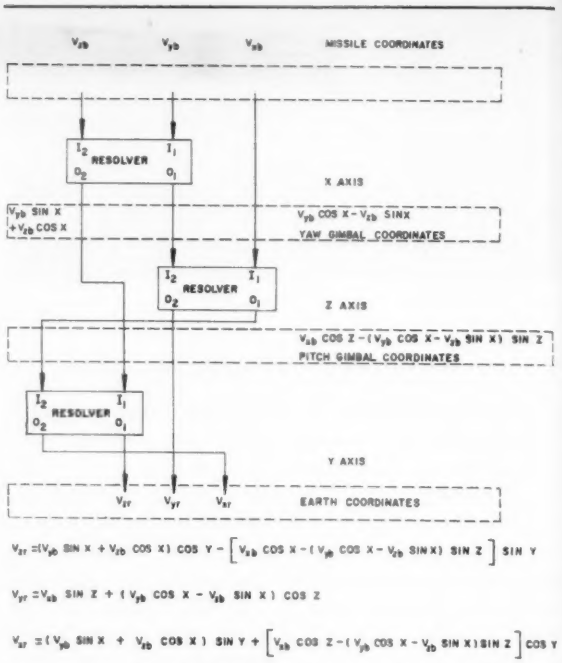


Fig. 5. Coordinate transformation—missile to earth.

to a normal computer simulation laboratory, permits the engineer, physicist, and mathematician to accurately perform this important step of physical simulation. The Flight Table is used to impart the rotational motion to the inertial elements being checked. The missile aerodynamics and kinematics are simulated, as before, on an operational d.c. computer.

Flight Table Resolver Resolution System

To do a complete job, the Flight Table must be more than just a precision servodriven device upon which motion sensitive components can be subjected to flight conditions in the laboratory. It should contain as many precision computing devices as are practical. The system referred to has five a.c. resolvers and one potentiometer associated with each gimbal axis. The yaw gimbal has a secant potentiometer for Euler angle computations. This permits usage of a vector resolution system. The static accuracy of one chain is 1/2 per cent full scale and a bandwidth of 250 cps.

Missile-to-Earth Coordinate Transformation

Through the usage of the resolver chains, it is possible to conduct simultaneous missile-to-earth coordinate transformations between the earth coordinate system and the aircraft body coordinate system. This can be performed for as many as four vectors by the Flight Table. Fig. 5 shows the step by step transformation from aircraft to earth coordinates. An inverse transformation allows the conversion from earth coordinate to missile coordinate.

Simulation Studies

With the addition of a Flight Table to a simulation laboratory a fair question would be, "In what areas of operation can this equipment be most profitably used?"

There are three basic usages that enhance the design and study of complex guidance and control systems. These are as follows:

(1) Open loop component or subsystem evaluation.
(2) Closed loop simulation.
(3) System analysis and synthesis.

Open Loop Evaluation

This is a broad category that includes any use of the Flight Table whereby the air vehicle steering, guidance, or control loop are not closed. It becomes apparent that since the Flight Table is not included in a loop, lower dynamic performance is required. This does not mean that valuable information cannot be derived even though the open loop testing does not make the most effective use of the Flight Table.

There are two major regions of interest in open loop testing: (1) dynamic behavior of inertial elements, and (2) environmental tests.

Dynamic Behavior

As previously stated, one of the paramount purposes of flight-table development is to subject inertial elements to the angular motions of flight. The dynamic response can be determined and the influence on a system or subsystem predicted.

Gyro Tests

A typical dynamic test of inertial elements was demonstrated in a recent evaluation of a newly developed gyro. The gyro, under study, was fastened to the roll gimbal of the Flight Table. The frequency response was obtained about the input and gimbal axes of the gyro for frequencies to 100 cps with the rate amplitude of the roll gimbal held at 1 rad./sec. The actual gyro sensitivity in millivolts per degree per second was determined.

An evaluation of two gyros was also completed on the Flight Table, in an open loop mode. The following pertinent tests were completed.

(1) Study rate calibration for negative and positive rates through their output limits.

(2) Frequency response about the input and gimbal axes.

(3) Frequency response with cross-coupling rates about the spin and gimbal axes.

(4) Frequency response about the gimbal axis with cross-coupling rates about the gyro spin axis.

(5) Response to step input rates.

Closed Loop Simulation

It should be pointed out, however, that the closed loop mode of operation is certainly the most profitable and efficient usage for the Flight Table and its associated electronics. The Table performs the function of a simulated high-performance air vehicle. The three major regions of closed loop simulation are generally considered to be: (1) stability studies, (2) trajectory studies, and (3) operational evaluation studies.

Because of the large number of simulation tests that have been made in the past, I shall only mention one typical closed loop test recently concluded.

Closed Loop Study

A major problem was encountered in determining the antenna and roll correction servo of a high-speed missile under conditions of high-missile roll rate and acceleration. It was necessary to define the limitations that launching might impose upon the missile system.

The effects of the initial launch on the seeker antenna roll correction servo were of major concern. A previous wind-tunnel test indicated that the effects of the flow field, surrounding the leading edge of the wing and the launching platform, subjected the missile to a high roll torque. For the purposes of the test, the missile antenna was secured to the roll gimbal of the Flight Table for physical simulation. Commands were then programed to simulate the actual missile roll motion at launch. The overall effects upon the missile gyroscope antenna assembly and the associated roll correction servo were evaluated.

Over 100 simulated launchings were completed to determine these design criteria. A complete plot of the operation of the seeker antenna roll correction system indicated that if the missile rates and accelerations at launch exceeded the capabilities of the roll mount drive system, a reduction in the allowable transverse gimbal angle would be necessary.

Other successful tests completed on the Flight Table include trajectory studies; operational evaluation studies; complete three-dimensional auto pilot studies, using eight inertial elements mounted to the Table; and a bomb directing set evaluation. A culmination of 150 to as many as 3,500 complete simulation runs were concluded on each study mentioned. The tests as outlined above were performed under the direction of the Bendix Research Laboratory Division in Detroit, Mich.

System Synthesis

As previously mentioned much valuable information has been accumulated using analog computers for system synthesis studies. The Flight Table, when used as a computing device, constitutes a formidable analog computing capacity. Assuming that one rack of commercial equipment contained one servo, driving four precision sine cards and four cosine cards with the associated electronics, approximately eight racks of equivalent computing equipment would be required.

(*Continued on page 44*)

The author considers the air-cooling technique of equipment cooling to be superior with respect to reliability, minimum fixed weight, and research and development effort required. With a sufficient amount of time, facilities, education, and personnel, the liquid system could be brought up to the equivalent air-technique "state-of-the-art," thus eliminating many of its disadvantages.

Equipment Cooling Techniques

for Supersonic Aircraft

Gilbert L. Roth
Convair, A Division of General Dynamics Corporation

THE DESIGN of airborne electronic and electrical equipment must incorporate sound thermal principles and be in accordance with the available cooling air temperatures and pressure drops. The designs must be integrated with the air conditioning system provided for the aircraft. Of primary value is the necessity of joint effort among electronic, packaging, control, and equipment cooling engineers and designers.

This study evaluates the many problems involved in the utilization of liquid and air cooling techniques applied to equipment cooling. Possible solutions to these problems are shown, and a comparative analysis of liquid versus air cooling systems is made.

The selection of an optimum cooling system should be based on an investigation of the cooling techniques and fluids with respect to

(1) Applicability of cooling method to specific equipment—i.e., feasibility.
(2) Service and maintenance.
(3) Allowable degradation of equipment accuracy.
(4) Temperature control requirements.
(5) Weight and spatial requirements.
(6) Installation problems.
(7) Overall system effect on airplane performance.
(8) Research and development cost and facilities.
(9) Reliability—component and overall system.
(10) Flexibility of system.

The actual cooling, within the equipment, is accomplished by any one or all of the following methods:

(1) Forced-air cooling achieved either by a *direct* technique—i.e., channeling the air directly over the equipment components—or by

(2) An *indirect technique* in which the equipment components are attached to a heat exchanger ("cold plate") and the air flows within the confines of the cold plate, not contacting the equipment directly.

(3) *Liquid* cooling, for our purposes, will be confined to the indirect technique noted in (2).

Mr. Roth is Project Propulsion Engineer at Fort Worth, Tex.

Design Basis

To further understand the basis upon which the equipment cooling system is selected, it is of value to appreciate the following basic points of design:

Material Temperature Limits

Typical component material temperature limits, shown in Table 1, indicate the wide range of maximum allowable values. This is an excellent indication of the difficulties involved in the proper distribution of both the components within the chassis and the problem of directing the coolant in the proper pattern.

Cooling Liquids' Physical Characteristics

The cooling liquids compared in Table 2 are those likely to be considered for equipment cooling. (These are not necessarily the final heat sinks.) With the exception of water solutions, all of the liquids require a relatively large pumping power, which is a function of $W(\Delta P)$.

Of the combustible liquids, the water-methyl alcohol appears superior. Nearly equally as acceptable are the water solutions of propylene glycol and ethyl alcohol. Of the noncombustible liquids, the water-ethylene glycol solution appears superior. The water-glycerin solution

TABLE 1
Material Temperature Limits

Component	Temperature Limits, ° F. (Ambient Unless Otherwise Stated)
Transistors, germanium type	10 to 125°F.
Transistors, special	265°F. max.
Porcelain-silver capacitors	390°F. max.
Resistors derated 25 per cent	260°F. max.
Wire insulation	480°F. max.
Subminiature tubes (surface temp.)	500°F. max.
Transformers	415°F. max.
Bonding resins	575°F. max.
Foam plastic sandwich	300°F. max.
Motors, surface temp.	−65 to 160°F.
Relays, surface temp.	−65 to 185°F.
Potentiometers, surface temp.	−65 to 185°F.

presents a severe warmup problem because of high viscosity at low temperatures.

Cold Plates and Their Geometrical Arrangements

Possible cold plate arrangements are shown in Figs. 1, 2, and 3. These are, of course, applicable to both liquid and air systems. A possible schematic arrangement for an entire electronic equipment bay is shown in Fig. 4 for liquid coolant and Fig. 5 for air coolant. These are sample methods.

Experience has shown the following:

(1) The liquid system has been used in few applications to date. It has been utilized in those specific areas where air cooling was not practical—e.g., very small and widely scattered units in confined areas.

(2) At present the air system, and in particular direct convective cooling, is necessary in the case of gyros and simular units.

(3) Air cold plates (indirect cooling) and direct air cooling applied to similar types of units require approximately the same weight in hardware—e.g., baffles, chimneys, clamps, etc., for indirect coolant method.

(4) The weight of hardware for cooling—for most packages, except those with Traveling Wave Tubes (TWT's)—is about 33 per cent of the total package weight. With TWT's, it is approximately 20 per cent of total package weight.

(5) In many instances electric blowers are required in units utilizing cold plates.

Design Analysis

Design Data

The aircraft mission profile—i.e., altitudes, speed, time—is the most logical starting point to ascertain the flight conditions that should be considered as the so-called "design-point."

A design-point condition is a single condition, or a small group of conditions, existing in a specification to which equipment manufacturers design and qualify their equipment and which the ultimate user sets up as a requirement in purchasing equipment.

Analysis indicates the equipment cooling system would best be designed to meet two conditions of flight —the basic system to supply equipment cooling during subsonic cruise, with the addition of water, fuel, and ammonia boilers to meet the high-speed condition. Actually, thermal lag will suppress the maximum adiabatic wall temperature to a degree dependent on the

TABLE 2
Comparison of Cooling Liquids

Liquid at 115°F.	C_p B.t.u. / lb.-°F.	μ lbs. / hr.-ft.	ρ lbs. / ft.^{3}	$W\Delta P$ lb. / hr. psf
Water	1.00	1.45	61.80	1.00
OS-45	0.54	28.00	55.30	11.32
Propylene glycol	0.64	33.90	63.60	6.39
Isobutyl-isopropyl	0.48	3.86	58.35	9.57
Water-methol alcohol	0.85	2.06	55.04	1.91
Water-propylene glycol	0.83	9.00	63.90	2.35
Water-ethylene glycol	0.77	6.30	66.35	2.56

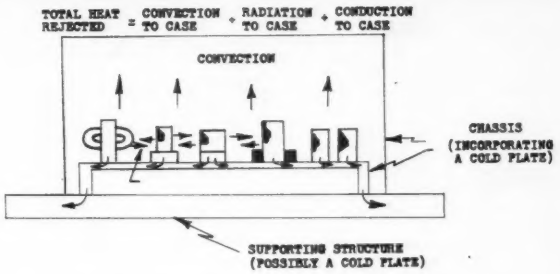


FIG. 1. Natural heat paths in avionic package.

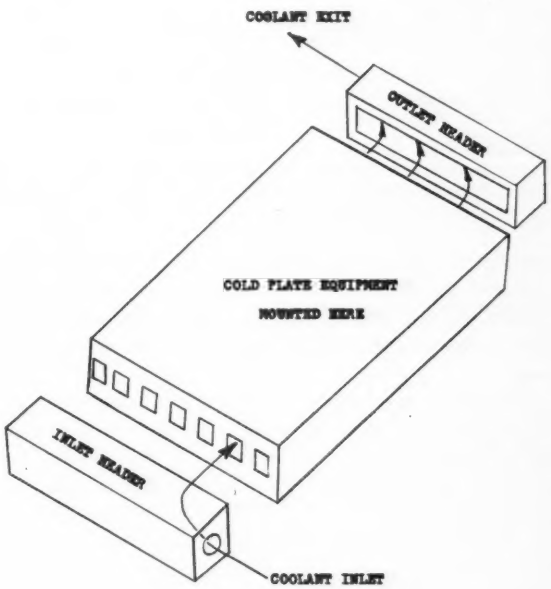
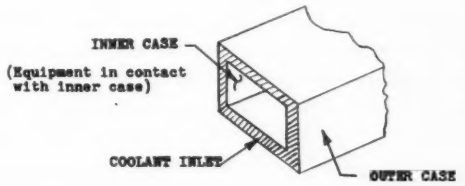


FIG. 2. Cold plate schematic.



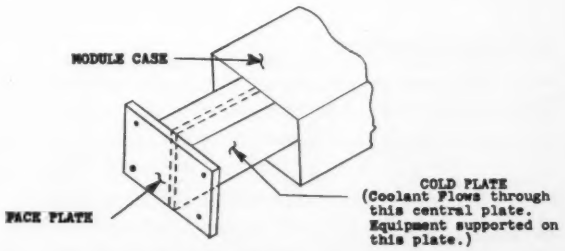
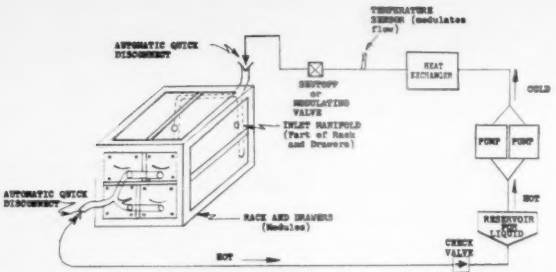


FIG. 3. Cold plate arrangements.



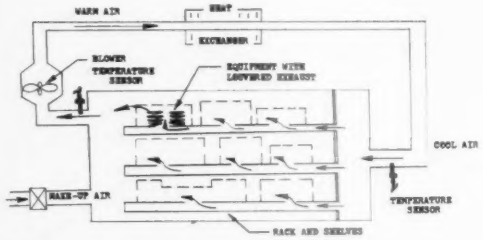


FIG. 4 (*top*). Schematic of liquid cooling system.
FIG. 5 (*bottom*). Schematic, air-cooled pressurized electronic compartment.

duration of the dash conditions and thus control the size and quantity of water boilers, etc. Idle engine power descent conditions are short-term transients and, if designed to, would require a system much too large.

The effect on equipment ambient air of aerodynamic heating (say 450°F. environment or higher) and solar radiation are reduced considerably by the thermal lag of the aircraft structure, equipment insulation, and the simple expedient of having the equipment exhaust air (at 250°F.) flow around the equipment before finally exhausting. Cursory analysis indicated that an air shield around the equipment of 250°F. is not materially affected by approximately 1 hour of high-speed flight (Mach 2 to 3). The maximum expected heat transfer from this 250°F. ambient into the package approximates 5 per cent of the equipment heat dissipation. Without this artificial atmosphere around the equipment, the expected heat transfer into the equipment could exceed 15 per cent of the equipment produced heat.

Procedure

Weight Analysis—An overall weight comparison of the various systems includes the expendable, fixed, and gross weights. The expendable weight is expended or consumed during the mission as, for example, the weight of expendable solids or liquids or the extra fuel which must be consumed to overcome system drag penalties. This indicates why weight and performance penalty studies should be integrated. The fixed weight consists of system items installed permanently in the aircraft. The gross weight combines the fixed and expendable weights.

In most instances the electronic equipment package weight attributed to cooling hardware will not vary appreciably between the cold plate (indirect) and the forced convection (direct) cooling techniques. Thus it is possible to determine this weight, on an approximate basis, by analytical means utilizing the definable parameters of the cold plate device. The total weight of the cooling hardware is approximated by (1) evaluating cold plate weight, for which an empirical analysis has been devised, and (2) adding to this weight an assumed increase for necessary clamps, binders, etc., equal to 75 per cent of the cold plate. This is based on the use of a near-optimum cold plate. Thus

Weight of cooling hardware (direct or indirect method) =
Weight of cold plate from heat-transfer analysis × 1.75

The weights of some liquids which may be used as coolants are shown in Table 2.

Calculated weights of liquid and air cold plates are shown in Table 3. For the same size cold plate (length and width only) and wattage dissipation, the metal weight for an air cold plate is about twice that of the liquid under laminar flow conditions. Adding the liquid weight to the weight of the cold plate adds about 80 to 90 per cent of the metal weight resulting in air and liquid cold plates of about the same overall weight.

TABLE 3
Tabulation of Liquid and Air Cold Plate Data

Water-ethylene glycol (40 per cent wt. of water)
Plate 26 in. long (Box 26 by 12 by 12 in.) and 12 in. wide
Heat input 872 watts—i.e., 436 watts/side
Plate made of aluminum (180 lbs./ft.^{3})
Laminar flow
Sea-level pressure, ambient

Plate No.	Total Plate Thickness, ft.	No. of Coolant Passages, n	Coolant Passage Width, ft., x	Coolant Passage Height, ft., y	Coolant Temp., °F. T_{in}	Coolant Temp., °F. T_{out}	Plate Temp., °F. Cold End	Plate Temp., °F. Hot End	Flow, lb./sec.	Δ_p in. H_2O	Approx. Plate Weight, lb.
Liquid Coolant Cold Plates											
1	0.01952	172	0.003	0.00625	100	120	102	126	0.0536	5	6.25
2	0.01938	89	0.003	0.00938	100	120	105	125	0.0536	5	6.57
3	0.01952	26	0.003	0.01152	120	160	135	175	0.0261	5	7.27
4	0.01895	21	0.003	0.00895	160	200	175	220	0.0254	5	7.17
Air Coolant Cold Plates											
1	0.0454	140	0.0041	0.012	70	225	200	235	0.0224	5	15
3	0.0435	170	0.0048	0.00935	80	235	175	250	0.0222	10	12.6

To determine the total weight of cooling hardware, multiply the weights of cold plate (plus liquid, if used) by 1.75. This weight 1.75 W_{cp} is also the weight of cooling hardware for a direct cooled unit. Extending this further, *since the weight of the electronic package is approximately three to five times that of the cooling hardware*, it is possible to approximate equipment weights. This may also be worked in the reverse manner—i.e., from known equipment weight to cooling hardware weight. An example of the above analysis follows.

Assume a cold plate from Table 3

Plate No. 4

W_{cp} = 7.17 lbs.

W_{liquid} = 0.9 × 7.17 lbs. = 6.45 lbs.

$W_{total\ plate}$ = W_{liquid} + $W_{cold\ plate}$ = 13.62 lbs.

$W_{total\ cooling\ hardware}$ = $W_{total\ plate}$ × 1.75 = 23.85 lbs.

= 24 lbs. (assumed)

with a total package weight equal to four times the cooling hardware weight. Then

$W_{total\ package}$ = 4 × 24 = 96 lbs.

Power in package = 872 watts

96/872 = 0.110 lb./watts

This is, of course, just a rough estimation and an average for typical packages.

Performance Penalty Study—Studies of the relative merits of various equipment cooling systems resulted in the following conclusions:

(1) The selection of the best system depends largely upon the speed at which the vehicle is traveling.

(2) Ram air system can be used to advantage up to Mach Number of approximately 1.2.

(3) Utilization of expendable liquids is superior to other systems at Mach Numbers greater than 1.8.

(4) A liquid heat sink is selected primarily on a basis of its latent heat and vapor pressure. Of course, chemical activity and toxicity must be considered. Water has the ability to absorb more heat than any other usable liquid, but its vapor pressure is so low that, as a heat sink, it is limited to the higher altitudes.

(5) Other liquids such as ammonia can be substituted for water, but the resulting systems will be heavier.

Studies indicate that there is no practical performance penalty difference between the air and liquid systems. Since fixed weight is important in determining payload or fuel capacity for take-off, the air system is perhaps the better of the two.

Reliability—The reliability of an item is generally defined as its probability of success in performing a specified task for a given operating time under the operational environment.

An overall reliability of 85 per cent for projected aircraft will be required, and the environmental control portion of the equipment should not degrade the system reliability to any degree under any flight, ground, or storage conditions.

For example, the liquid system is a closed system, and any loss of the primary coolant being supplied to the electronic equipment packages cannot be made up. Thus a leak in a liquid system will cause a reduction in reliability. In an air system, a leak, if not too large, can be overcome by increasing the overall airflow or taking a reduction in the cooling capacity of the system.

Thus, on a reliability basis, the air system appears to be the best choice.

Applicability to Electronic Equipment—In many instances the electronic equipment must, owing to inherent physical and operational characteristics, be air cooled by direct means. This means no cold plate can be made to do the job properly. If a liquid system is used, additional blowers would be required to circulate the cool air over the item.

Navigation items and others using gyros and small rotating mechanisms would be involved here.

The cold plate, with careful design, can be made to fit most types of equipment. The air system can be made to fit any present or expected equipment cooling requirements.

Installation Problems—The trend is toward packaging in "file drawer" or "rack and drawer" configuration (see Fig. 4). File drawer setups require a subchassis division to obtain the individual drawers and is a major electronics problem.

Some installation problems are (1) equipment interaction in adjacent drawers; (2) heat transfer; (3) shock and vibration; (4) failure of disconnects used with liquids to seal, resulting in loss and possible disruption of cooling system.

TABLE 4
Electronic Package Cold Plate

Advantages	Disadvantages
(1) The coolant flow is completely separated from the electronic equipment. This permits hermetically sealed units to be cooled easily.	(1) Many units must be cooled by a direct blast of cooling air. This would require either additional airflow ducting and/or a blower.
(2) Cold plates can be designed to serve the dual purpose of becoming a part of the equipment primary structure or as a storage shelf for plug-in modular packages equipment.	(2) If the module system is used, it means replacement of whole black boxes rather than individual pieces.
(3) The cooling fluid channels of a cold plate can be designed practically.	(3) Vibration of cold plate due to cooling fluid and/or other pulsing modes can cause "noise" interference.
(4) The cold plate is able to conduct heat, concentrated at a region, by spreading it over a relatively large area compared with the surface area available at the heat source.	(4) It is sometimes necessary to isolate elements with no heat dissipation from those having high heat dissipation.
	(5) Excessive temperature gradient between plate and equipment being cooled.

Direct Air Cooling (by forced air) has the following advantages:

(1) Possible methods of arrangement, placement, mounting, fastening, finning, baffling, ducting, and other factors are so numerous that innumerable cooling designs are possible for one package.

(2) Ability to cool specific units as required, thus optimizing required airflow.

(3) Direct cooling permits the designer to enjoy a greater range of available inlet temperatures, weight of airflow, and exhaust temperatures.

Comparison of Cold Plate vs. Direct Cooling

The use of cold plates, whether air or liquid, has certain advantages and disadvantages as shown in Table 4.

Conclusions

The comparative study of both liquid and air systems for cooling electronic equipment has shown that the air cooling method is best suited to *present* aircraft. The air system selection is based on the following:

(1) *Reliability:* The reliability of the air system is inherently better than that of the liquid system.

(2) *Weight:* The overall system fixed weight is less for the air system. The weight attributable to the hardware required on or within an electronic package is approximately the same for air and liquid systems.

(3) *Performance penalty:* Based on equivalent weights—i.e., fixed weight plus thrust reduction to operate system—the two systems have almost identical performance penalties.

(4) *System flexibility:* The air system is more flexible than a liquid system. This is indicated by the change in air mass flow rate to meet varying flight conditions. The liquid coolant mass in the system is constant.

(5) *Applicability of cooling system:* The air system can be used directly with any and all equipment while the liquid coolant cannot be used directly to cool such items as gyros.

(6) *Manufacturer's problem:* The industry has done little with liquid cooling to date. If we are to use the liquid system, it would require education of concerned personnel, new facilities, and a large amount of test work. Air as a coolant presents no such problem.

(7) *Maintenance:* The major difference between the two systems lies in the draining requirement for the liquid system.

Recommendations

Increasing the cooling efficiency of any equipment cooling system must be a continuing process. The following investigations should be pursued:

(1) Temperature control of gyros.

(2) Means of protection of electronic equipment from abnormal environmental conditions.

(3) Transient temperature correlations with environmental and electrical variations.

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✦ ✦ ✦

Three Axis Flight Simulator Systems (Continued from page 39)

I hasten to say, however, that the equipment is best utilized when applied in physical simulation closing the loop on a system.

New Concepts and Usages

The efficient use of a Flight Table in conjunction with a controlled target simulator is now a reality with much engineering effort being directed at that area.

One user of a Flight Table is currently giving serious thought to the possibility of adding the translation vector to the present angular motions. This physical simulation would be performed by the usage of a single or multiaxis Flight Table mounted to a translation device such as a sled.

Conclusion

Physical simulation is here to stay; indeed it has been with us for some time. It has proved inexpensive when compared to the only other method of component checkout—actual flight tests. The Flight Table has proved to be of inestimable value due to its computing capacity and ability to physically mount and utilize the missile hardware in a closed loop.

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XUM

The Role of Manned Balloons in the Exploration of Space

The subject of this paper is illuminated with an extensive report of the authors' observations and experiences in the Strato-Lab High #2 flight of October 18, 1957.

Malcolm D. Ross, Office of Naval Research
and
M. Lee Lewis, Winzen Research Inc.

ALTHOUGH PILOTED FREE BALLOONS may seem old fashioned and outmoded as we approach the era of manned flight into space, experimentation from manned balloons can contribute basic knowledge of great importance for man's exploration beyond our atmosphere.

There are two major areas in which manned balloon flights can provide valuable information to aid engineers and scientists charged with determining needs, specifications, and designs of manned earth satellites and true space vehicles. The two areas include human factors studies and the broad field of extraterrestrial measurements.

In the studies of human factors, balloon flight personnel are subjects. Much has been accomplished in this area, but even more significant accomplishments can—and must—be made in the future.

In the area of extraterrestrial measurements it is essential that astronomers and astrophysicists be included in future balloon crews for the exciting opportunity to peer out into space from the balloon-borne observatory. They will assist in the exploration of space by utilizing a currently available vehicle, the balloon, in lieu of an earth satellite or space ship to obtain basic information. They will also be designing, using, and establishing techniques for prototypes of instrumentation which will eventually be used in space vehicles. A distinct challenge is therefore offered to resourceful and imaginative scientists in this prospecting area. The opportunity exists to use the manned balloon laboratory, floating above 98 per cent, or more, of our atmosphere, and explore space *now*.

Condensed and revised exclusively for this issue of *Aero/Space Engineering* from the paper of the same title presented before the Meteorology Session, held in cooperation with the American Meteorological Society, at the IAS 26th Annual Meeting, N.Y., Jan. 27–30, 1958.

The authors are Physicist and Operations Manager, respectively.

Background

In 1783, Montgolfier launched the first free balloon in France; then the first human, Pilatre de Rozier, also a Frenchman, ventured aloft in a balloon. This is, therefore, the 175th anniversary year of man's first flight. During those 175 years, many observations have been made from balloons as man first explored in the earth's atmosphere. Jeffries,[1] Zakharov,[2] Glaisher,[3] and Bert[4] are only a few of many who have used this tool for exploratory research. Manned balloon flights pertinent to space flight, however, began as recently as 1931 when Auguste Piccard[5] made the first of his two historic stratospheric ascents.

From 1931 through 1957 there were a total of 17 manned balloon flights into the stratosphere. Ten were made in the 1931–1935 period, then none for almost 21 years. From August, 1956, to October, 1957, there were seven manned stratospheric ascents in this country during the renaissance of free ballooning with plastic balloons.

Five of the recent flights were part of the Navy

Strato-Lab program and two were under the Air Force Man High project. Of the 17 flights, 14 have used sealed cabins. Thus, a meager but valuable source of information exists which documents man's reactions at high altitude in a completely artificial environment. Table 1 summarizes the 14 sealed cabin stratospheric flights.

In 1956, Captain N. L. Barr, MC, USN, of the Navy Bureau of Medicine and Surgery, started making direct measurements of human reactions during Strato-Lab balloon flights. These were the first ever made of humans flying in a sealed cabin with an artificial environment. Subsequent to the report of his findings[6] from two 1956 ascents, he has continued his pioneering work with measurements on two 1957 Strato-Lab flights. Although his work has been supplemented with U.S. Air Force investigations, his quantitative measurements are unique because his subjects were two-man crews in each of the four Strato-Lab ascents studied. The authors have been privileged, along with Strato-Lab alternate, Charles B. Moore, Jr., of Arthur D. Little, Inc., to serve as subjects.

All high-altitude balloon flights have contributed in a qualitative sense to the total knowledge of the cosmic radiation health hazard. According to Schaefer,[7] however, radiobiological studies are of little value, when applied to man in space, unless made at altitudes of at least 120,000 ft. or higher. Thus it appears that definitive contributions to space medicine are lacking in this area and await higher altitude flights.

A further review indicates that much has been accomplished in studying our own atmosphere, but

TABLE 1
Summary of Balloon Flights Using Sealed Cabin Systems

Date	Balloon and Place	Alt. of Balloon & Cabin	Personnel	Air Cond. System	Remarks
27 May 1931	F.N.R.S Augsburg, Germany	51,458 10,000	A. Piccard P. Kipfer	Comb. gaseous O_2 and liquid O_2. Chemicals.	Reached 106°F. in gondola. (Top was black and bottom was white)
18 Aug. 1932	F.N.R.S. Zurich, Switzerland	53,152 10,000	A. Piccard M. Cosyns	" " "	Gondola temp. as low as 0°F. (White all over)
30 Sept. 1933	USSR Moscow, Russia	60,695 10,000	Prokovief Birnbaum Godunow	Liquid O_2, gas O_2 for backup. Natron lime, sulphuric acid, and phosphorous pentoxide.	High humidity.
20 Nov. 1933	Century of Progress Akron, Ohio	61,237 10,000	T. Settle C. Fordney	Liquid O_2 and chemicals.	
30 Jan. 1934	Osoaviakhim Moscow, Russia	72,000 (approx.) 10,000	Fedosienko Wasienko I. Usyskin	Liquid O_2 and chemicals.	Cabin free fell from 50,000 feet. All perished.
28 July 1934	Explorer Rapid City, So. Dak.	60,613 13,000	W. Kepner O. Anderson A. Stevens	Liquid O_2 and chemicals.	Balloon failed, crew parachuted safely.
18 Aug. 1934	F.N.R.S. Hour Havenne, Belgium	52,329 10,000	M. Cosyns Van der Elst	Liquid O_2 and chemicals.	
23 Oct. 1934	Century of Progress Detroit, Mich.	57,579 10,000	J. Piccard J. Piccard	Liquid O_2. Silica gel, sodium hydroxide and magnesium perchlorate.	Functioned well.
26 July 1935	USSR	52,000	Warigo Christofil Prilucki	Liquid O_2 and chemicals.	Successful.
11 Nov. 1935	Explorer II Rapid City, So. Dak.	72,395 13,500	O. Anderson A. Stevens	Mixture of liquid O_2 and N_2. Sodium hydroxide.	Successful. Outstanding scientific contributions.
8 Nov. 1956	Strato-Lab Rapid City, So. Dak.	76,000 17,500	M. Ross M. Lewis	Liquid O_2. Lithium hydroxide, lithium chloride.	Malfunction of balloon. Rapid descent, safe landing.
2 June 1957	Man High Minneapolis, Minn.	96,000 25,000	J. Kittinger	Liquid O_2 and helium. Lithium hydroxide, lithium chloride, magnesium perchlorate.	Successful. First solo with sealed cabin in stratosphere.
19–20 Aug. 1957	Man High Crosby, Minn.	101,516* 25,000	D. Simons	" " "	Successful day-night flight of 32 hours. Had elevated CO_2 and temperature.
18 Oct. 1957	Strato-Lab Crosby, Minn.	85,700 17,000	M. Ross M. Lewis	Liquid O_2. Lithium hydroxide, lithium chloride, molecular sieve.	Successful, routine. Elevated humidity and temperature.

* Official world altitude record.

little has been directed toward the region beyond our atmosphere. The historic Explorer II made a tremendously important scientific contribution.[8] But, other than investigations of cosmic ray activity and exposures of biological specimens, all information was geophysical. Major Simons, although equipped with a 5-in. telescope, reported capsule stability problems[9] with no astrophysical measurements.

A. Dollfus, in France, has made progress in this area of science. During a tropospheric balloon flight to about 20,000 ft. in 1954 he attempted measurements of the water vapor content of the Martian atmosphere. He concluded,[10] however, that there was too much residual terrestrial water vapor above him, and measurements should be repeated from the stratosphere. Dollfus also made tropospheric balloon flights for solar studies in collaboration with the British astronomers Blackwell and Dewhirst. Although his solar granulation photographs are not comparable with the ones taken from unmanned stratospheric balloons by Schwarzschild,[11] it is possible that additional altitude would also produce sharp photographs with Dollfus' 11-in. telescope.

Vaeth[12] has discussed the astronomical future with manned plastic balloons, and the proposal of Dr. John Strong to use the manned plastic balloon and a unique telescope-spectrograph to investigate the Martian atmosphere has previously been reported.[13,14] Since his proposed research became a part of the Navy Strato-Lab program, he suggested that the authors make measurements to ascertain the gondola stability while floating at altitude. The acceptable motion limits with his system include rotation of 0.1°/sec. and a maximum vertical axis displacement of ±1°. The motion was measured on a recent flight and the results will be considered in a later section.

The Strato-Lab Program

The first important work with plastic balloons began in 1935 when Dr. Jean Piccard experimented with cellophane balloons at the Bartol Foundation. Later, in collaboration with Dr. John Akerman at the University of Minnesota, this experimentation was extended and successful unmanned flights were conducted in 1936.[15]

In 1946 the Office of Naval Research supported a Project, called Helios, with General Mills, Inc., of Minneapolis, Minn., which was the dream of Piccard's for a cluster of plastic balloons to carry a two-man crew in a sealed gondola to an altitude of 100,000 ft. for research. After a year's study, investigation of plastic materials, and some experimentation, it was decided by the U.S. Navy that Helios was premature but that the plastic balloon appeared attractive for research. ONR then initiated Project Skyhook to utilize single plastic balloons for unmanned flights with instruments carried to stratospheric altitudes. The first successful Skyhook flight was made September 25, 1947, and the project is still supported by ONR (in recent years jointly with the Atomic Energy Commission) as a unique means for collecting data over a period of many hours while the balloons float at a constant density level.

Table 2
Summary of Stratospheric Flights Conducted Under Navy Strato-Lab Program

Date	Altitude	Personnel	Objective	Remarks
10 Aug. 1956	40,000	M. Ross M. Lewis	Geophysical and physiological studies.	First manned flight into stratosphere on plastic balloon. First stratospheric balloon ascent since 1935. Open basket gondola with ambient conditions. Gaseous O_2. Very successful flight.
24 Sept. 1956	42,000	H. Froehlich K. Lang	Geophysical.	Set new unofficial altitude record for open basket gondola. Liquid O_2. Very successful flight.
8 Nov. 1956	76,000	M. Ross M. Lewis	Test system, provide subjects for aeromedical research.	First sealed cabin flight on plastic balloon. System, in general, adequate. Malfunction of balloon caused apid but safe descent. Excellent data related to physiological stress of subjects.
19 Aug. 1957	38,000	H. Froehlich K. Lang	Geophysical.	Open gondola. Liquid O_2. Excellent flight. Made experiments successfully.
18 Oct. 1957	85,700	M. Ross M. Lewis	Aeromedical, geophysical, astrophysical, and evaluation of system.	Quite successful, almost routine. Highest known altitude for a two-man crew. Sealed cabin system and balloon performed well with exception of humidity and temperature control. Good experimental data.

In 1954, ONR originated the Strato-Lab manned plastic balloon program to extend the research capability so ably demonstrated with the unmanned Skyhook plastic balloon. It was conceived as a manned laboratory floating at any desired altitude up to 100,000 ft. or higher. Its objective was to provide a system for research which required people—as subjects, as scientists—to use special instrumentation for exploratory observations, or to evaluate various military components and techniques.

A number of ascents have been made under Strato-Lab. Most have been conducted to obtain geophysical information at altitudes well below the tropopause. Two were made into the upper regions of the troposphere in connection with observations of thunderstorm development[16] and five flights were made into the stratosphere during 1956 and 1957. The latter are chronicled in Table 2.

It is evident that the sealed cabin system flights are the ones most pertinent to the consideration of space exploration. Since the flight of November 8, 1956, has been reported elsewhere,[17, 18, 19] the flight of October 18, 1957, designated Strato-Lab High #2, will be discussed here.

Flight of Strato-Lab High #2

Contractor for the flight, Winzen Research Inc., Minneapolis, Minn., was responsible for readying the gondola, building the balloon, and conducting the launch. While airborne, the authors (both on active

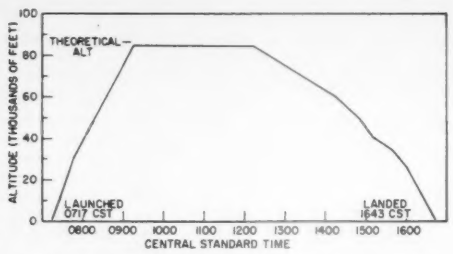

FIG. 1. Time-altitude plot; Strato-Lab High #2, October 18, 1957.

Navy duty as Lieutenant Commanders) were in command of the flight. Comdr. R. C. Cochran, USN, ONR, was Operations Officer and coordinated the various tracking aircraft and ground vehicles.

Donald Foster, project engineer, prepared the gondola for flight and conducted preflight environmental tests. Otto C. Winzen directed his crew during the early morning hours for the inflation and launch, assisted during the tracking, and supervised recovery. The gondola, except for minor changes and some additional equipment, had been flown before so earlier descriptions[20, 21] are adequate.

The balloon was constructed of two mil gage polyethylene with load bearing glass fiber tapes. It had the "natural" shape at ceiling altitude with a diameter of approximately 172 ft. and displaced about 2 million cu.ft. The electric valve in the balloon crown was operated from within the gondola to allow control of vertical movement. A large unpacked cargo parachute was used as a load line between balloon and gondola, available in emergency as an automatic safety device.

The launch, at 0717 CST, was smooth and the ascent out of an open pit iron mine near Crosby, Minn., uneventful. To assure a swift departure from the sharp nearby walls of the pit an excess amount of helium was used. At an altitude of about 2,000 ft. above the surface, the indicated rate of rise was reduced from 1,200 ft. per min. to about 700 ft. per min. by valving. At 10,000 ft. the lower hatch was closed and the gondola sealed. From then on the flight was routine with an indicated peak altitude of 85,700 ft. The plot of altitude versus time is shown in Fig. 1. The flight trajectory (Fig. 2) was primarily toward the east and the landing was made near Hermansville, Mich., at 1643 CST.

Balloon performance was excellent as indicated in the floating altitude portion—almost 3 hours—illustrated in Fig. 1. No ballast was used except to facilitate landing. The latter was accomplished with expendable batteries which performed the dual function of providing power and serving as ballast. Except for a few pounds consumed immediately before landing, the full 257-lb. load of iron dust ballast remained aboard.

RESULTS OF STRATO-LAB HIGH #2

Measurements or observations made during the flight include three areas: human, physical, and stability. Each will be discussed.

Human Factors

Included were quantitative measurements, as well as purely subjective reactions of the crew.

(1) *Physiological Reactions*—Heart and respiratory information were transmitted by radio (automatically) and received aboard a Navy R5D type aircraft. Physiological fitness of the subjects was continuously evaluated and the data tape recorded for postflight analysis. Blood and urine samples were collected at scheduled times for analysis to reflect chemical changes indicative of physiological stress. The results, when fully analyzed, will be reported by Dr. Barr.

(2) *Environmental Conditions*—These were reported at regular intervals by radio and tape recorded, and the more significant items logged in the flight journal. A standard 35-mm. camera photographed the instrument panel at 2 min. intervals which provided additional cabin environment information. Table 3 contains a summary of the conditions for this flight, which is believed to have reached the highest altitude ever attained by a two-man crew.

(3) *Subjective Physiological Reactions*—The human reactions, although purely subjective, are worthy of mention. The Air Force MC-3 type partial pressure suit was worn under the inner half of a standard U.S. Navy cold weather suit. A back pack personnel parachute and an emergency bail-out seat pan were added to the above.

Simple tasks were performed throughout the flight. These included the reading of various instruments, using some of these at the various ports, taking photographs, and related activity. As a result of this moderate movement and the discomfort experienced at ceiling altitude it was recognized that the clothing and protective equipment were not fully compatible with the concept of Strato-Lab as a research "laboratory." It is believed that if each individual had remained seated, with no need to move around the gondola, the entire flight would have been made in relative comfort

FIG. 2.

TABLE 3
Partial Climate Data from Strato-Lab High #2 Flight on October 18, 1957

Time (CST)	Ambient Alt. (Ft.)	Internal Alt. (Ft.)	Int. Temp. (°F.)	Amb. Temp. (°C.)	Int. Rel. Hum. (%)	pO_2 (mm. Hg)	CO_2 (%)	O_2 Remain. (Liters)
0717	Launched							
0726	10,000 - Closed hatch. Set O_2 converter at 20 l./min.							
0734	18,000	14,200	52	−20	66	115	0	4.1
0743	25,000	18,220	49	−40	57	115	0	3.9
0747	30,000							
0802	40,000	18,200	43	−50	57	155	0	3.3
0819	50,000	17,600				180	0	
0826	55,000	17,500	43		52	180	0	3.1
0843	65,000							
0850	Set O_2 converter flow at 1 l./min.							
0851	70,000							
0900	75,000	17,300	48	−50	55	175	0	3.0
0906	80,000							
0917	85,500	16,950	52	−45	59	185	0	3.0
0918	85,200							
0920	Turned O_2 converter off							
0926	85,700							
0948	85,400							
1000	85,400	16,800	57	−45	66	180	0	3.0
1030	85,200	16,750	67	−50	56	175	0	2.9
1100	85,400	16,500	70	−50	57	175	0	2.9
	Set O_2 converter at 2 l./min.							
1130	85,400	17,500	73	−50	63	170	0	2.9
1200	85,100	17,100	76	−45	61	175	0	2.8
	Set O_2 converter at 1 l./min.							
1235	81,800	16,500	80	−40	60	180	0	2.8
1255	77,000	16,500	77	−50	65	180	0	2.7
1315	73,600		78	−50	58	180	0	2.5
1335	68,500	16,500	76	−50	72	185	0	2.5
1405	64,600	16,800	75	−50	61	180	0	2.5
1435	55,000	16,800	72	−50	63	180	0	2.5
1500	44,250	16,800	68	−50	71	185	1	2.5
1530	37,000	17,300	65		72		0	2.3
1643	Landed							

despite the elevated temperature and humidity. The combination of restrictive protective clothing and related equipment, the temperature, humidity, and the moderate activity, however, proved at times to be highly fatiguing, even intolerable. Relief was accomplished by terminating the assigned work.

The above experience cannot be overemphasized relative to the decrease of human efficiency in an abnormal and uncomfortable situation.

(4) *Subjective Observations of Interior Lighting*—No significant perceptual difficulties were encountered within the gondola as a result of the brightness contrasts of exterior reflected light. Unfortunately, no measurements were taken to supplement the data and discussions of Barr,[22] Cibis,[23] and Whiteside[24] in contemplating the problems of vision at high altitude. The sharp contrasts they reported were noted, particularly the contrast from outside to inside. After looking at the bright cumulus below, an adjustment period of approximately 10 sec. was needed for visual adaptation to the reduced brightness level inside the gondola. However, inside the spherical gondola the contrasts did not appear to be significant with respect to the brightness differences in reflected light from the dark sky above, the horizon, or the bright clouds below. Rather, the significant interior contrasts came from spots of direct sunlight which entered through the ports and were almost brilliant sources of reflected light on the interior gondola walls. Otherwise the interior of the gondola, which was painted white, was well lighted by the natural exterior brightness and did not seem to have the deep shadows and sharp contrasts which were as extreme as those measured in typical aircraft cockpits. All instruments were easily read, except when completely blotted from view by the spot of direct reflected sunlight.

(5) *Subjective Psychological Reactions*—On two previous flights the authors have observed and reported[25] the feeling of "earth separation" and a pronounced urge to fly on and on. The feeling was present again on this flight except to a lesser degree than noted on the earlier flights. Since all available time of each person was devoted to tasks assigned prior to flight, there were very few idle moments. As suggested by Clark and Graybiel,[26] that could account for the less pronounced awareness of the earth separation phenomenon, at least in part.

Physical Measurements

Included were geophysical and astrophysical observations.

(1) *Geophysical*

(a) *Air Sampling*—Four evacuated 50-liter stainless steel flasks, prepared by Dr. Ruven Smith of the Naval Ordnance Test Station, China Lake, Calif., were used to collect air samples on descent, to minimize contamination from balloon helium. The levels were at 5,000 ft. intervals between 84,000 ft. and 69,000 ft. The samples, analyzed with the mass spectrometer, should be

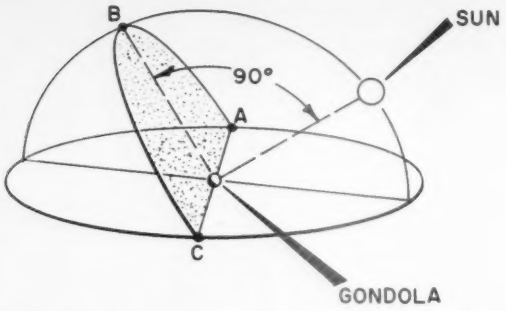

FIG. 3. Arc *ABC* for measurements of sky brightness.

of interest relative to the chemistry of the stratosphere when Dr. Smith discloses his findings.

(b) *Sky Brightness*—A Luckiesh-Taylor Brightness Meter, modified with a blue color reference to match the sky background, was provided by Dr. R. Tousey and M. Koomen of the Naval Research Laboratory for sky brightness measurements which they had suggested.

The personal discomforts noted earlier prevented carrying out the planned measurements of polarized and unpolarized light at various altitudes and at particular zenith angles. One specific measurement desired was along the arc of a plane perpendicular to a line from the gondola to the sun. This hypothetical arc from horizon to horizon is illustrated as *ABC* in Fig. 3. Only four measurements were made, on the *CB* segment, and the results are contained in Table 4. Sheer fatigue and discomfort prevented the completion of this observation.

(c) *Exterior Illumination*—A simple, yet quantitative, measure of illumination from the balloon, sky, horizon, and clouds was obtained with an ordinary Weston exposure meter. These data are compiled in Table 5.

The exposure meter readings are admittedly crude when compared with the refined sky brightness measurements made by Teele,[27] Tousey and Hulburt,[28] Barr,[29] and others. The readings are unique, however, as a complete synoptic (essentially) indication of sky and earth illumination from a point in the stratosphere.

(d) *Observations With Interference Filters*—Negative results were obtained in an effort to detect atmospheric constituents, sodium in particular, with interference filters loaned by Dr. Tousey. The observational technique was quite simple. The observer scanned the horizon, and region immediately above, while looking through the filters and rotating them slowly through an angle of 45°.

(e) *Planned Measurements Not Made*—Instrumentation was carried to make measurements for the Naval Ordnance Test Station. The equipment, however, became inoperative at the last minute.

The authors shared keen disappointment with the chief investigator, E. V. Ashburn, who had labored diligently and painstakingly to prepare the instrumentation. Observations were planned to measure the diffuse reflectance of earth and sky from the nadir to the edge of the balloon with a very sensitive radiometer. Also sky brightness at various altitudes was planned with a special sky photometer. Measurements of atmospheric humidity and transmissivity were also planned. Temperature data were obtained with the technique of black and white thermistors whirling at the end of an extension member attached to the gondola. This system was developed for Strato-Lab by Dr. V. E. Suomi, consultant to Winzen Research Inc. The temperature data are contained in Table 3.

(2) *Astrophysical Information*

(a) *Primary Cosmic Radiation*—With a special gamma ray telescope, developed by Dr. R. Danielson and Prof. E. P. Ney, of the University of Minnesota, some measurements were made to determine whether or not the primary gamma, which is a portion of the total primary cosmic radiation, is generated by the sun. Analysis of the data, which were recorded on film, is incomplete but their preliminary study indicates that the particular radiation investigated does not originate with the sun. When their evaluation is completed, the technique and result will be appropriately reported by them.

(b) *Lunar Observation*—Although not precisely astrophysical it was an extraterrestrial observation. Between 0930 CST and local noon the authors looked at the moon a number of times. No attempt was made to use telescopes provided by the Naval Observatory.

The moon appeared stark, unreal. It also appeared larger, brighter, and sharper (no shimmer) than when viewed from the ground. Although the elevation angle of the moon was not high during the times observed, the

TABLE 4

Sky Brightness Measurements With Luckiesh–Taylor Brightness Meter. Altitude 85,400 Ft. (MSL). 1100 CST Sun Position, Azimuth—165°, Elevation Angle—36°

Time (CST)	Azimuth Angle (Degrees)	Zenith Angle (Degrees)	Brightness* (Foot Lamberts)
1115	255	90**	56
1120	270	70	40
1124	285	55	23
1127	315	40	18

* Because of disagreement between preflight and postflight instrument calibration, these absolute values may be in error by a factor of 2 but are correct with relation to each other.
** Approximately 5° above horizon.

TABLE 5

Illumination Observations, With Weston II Exposure Meter

Time (CST)	Azimuth Angle (Degrees)	Zenith Angle (Degrees)	Illumination (Scale Units 0–1,600)
	...	0**	700
All	000	35	75
these	135	35	Off Scale(High)
obs.	215	35	100
were	160	45	Off Scale(High)
made	000	90*	400
between	350	120	1000
0955	050	157	1200
and	160	157	1600
1010.	270	157	800

* 5° above horizon.
** Looking at balloon through top port.

contrast between it and the deep blue-black sky background was enhanced so it appeared almost black immediately surrounding the moon. It also gave the impression of being coldly beautiful, somewhat awesome, not at all an inviting place for the exploration by some future space crew.

(c) *Planned Observations Not Made*—In collaboration with Dr. John Hall and A. H. Mikesell of the Naval Observatory it was planned to dark adapt and make observations of the atmospheric effect on "seeing." For this purpose the Naval Observatory had provided telescopes with eyepieces allowing variable magnification. The objective required seeing the stars in daytime with various degrees of magnification and at different zenith angles. When the flight plan directed attention to dark adapting, it was past the scheduled time to initiate a descent. Thus, regretfully, it was necessary to return to the schedule so stellar observational plans were abandoned and valving commenced, 40 min. late, to start down. The decision was wise as the landing was made within minutes of local sunset.

Sputnik I was in its orbit while Strato-Lab High #2 was aloft. In the days immediately prior to the flight an attempt was made to meet the exploratory challenge presented by man's first artificial earth satellite. It was rather obvious that any observation of the satellite, if indeed any was feasible, from the balloon platform would have to be simple. Photography was the most reasonable possibility. For this purpose W. Garrett, of the National Geographic Society, sent a special camera, lens, tripod, and film for use if there was an opportunity. Unfortunately there was not.

Stability Assessment

The general stability was observed with a compass, bubble type levels, and movement of a spot of sunlight on the instrument panel.

(1) *Compass Indication*—Although the compass was not included in the time-lapse series of documentary photographs taken, its change was observed during the time at altitude. Total angular rotation of the gondola was about 70° in one direction, then a partial return. The log indicates arrival at floating altitude at 0917 CST with a heading of 330°. At 0930 CST the compass read 340° with no apparent change in this heading for 25 min. At 0955 CST the gondola started a slow clockwise rotation and by 1030 CST the heading was 040°. It then started a slow rotation in the opposite direction. No further log records were kept on the compass reading but it was noted that the gondola heading was always between 330° and 040° during the floating period (0917 CST to 1210 CST). Despite the lack of quantitative records for these measurements the 35° amplitude of the rotation appears to have been less than, but essentially consistent with, that of Explorer II, which was reported by Brombacher and Trent[30] as varying from 20 to 90° while at altitude.

(2) *Bubble Level Readings*—Two pairs of levels were arranged in 90° planes on the instrument panel to provide a quantitative indication of angular change in the vertical axis (tilt) of the system. The levels were observed several times during the flight; however no records were kept because of the time-lapse photo record. The film quality, however, was not adequate to note bubble movements. The casual observations during the flight, therefore, are the only results from these rather crude, but adequate, indicators.

TABLE 6
Rotation and Tilt of Gondola from Analysis of Sun Spot Movement on Instrument Panel

Time (CST)	Azimuth Change of Sun Spot from Ref. Point (Deg.)	Azimuth Change of Sun (Deg.)	Actual Rotation of Gondola (Deg.)	Rate of Rotation (Deg./min.)	Gondola Tilt	Tilt Rate (Deg./min.)
1042	....	...	.....	....	....	....
				2.3		0.27
1044	5.09	0.5	4.59	....	0.54	....
				3.48		0.18
1046	12.55	1.0	11.55	....	0.89	....
				1.92		0
1048	16.90	1.5	15.40	....	0.89	....
				3.51		0.27
1050	10.38	2.0	8.38	....	0.36	....
				2.67		0.45
1052	−0.54	2.5	3.04	....	−0.54	....

It appeared that vertical tilt was less than 1° at altitude except for one brief period. During the latter one of us deliberately "rocked the boat" with several rapid body motions from side to side. An immediately perceptible gondola motion resulted but it (apparently) damped out in a few minutes.

(3) *Sun Spot Photographs*—All time-lapse instrument panel photographs were examined to measure rotation and tilt of the gondola from the motion of the spot of reflected sunlight which appeared on the panel.

The spot was only observable during a portion of this period. Excursions of the authors back and forth across the gondola blocked out the instrument panel in some of the photographs which further reduced the number available for postflight analysis. Nevertheless, a representative sample met the conditions desired and were analyzed. The gondola motions indicated by the movement of the spot of sunlight are not truly representative of "quiet" conditions since human movements are undoubtedly important factors and the crew moved around freely. Thus, the results in Table 6 may appear pessimistic but must be interpreted as extremely conservative indications of the stability. Despite this, the 10 min. segment analyzed indicates stability which is fully compatible with the need of Professor Strong for his telescope-spectrograph.

PLANS FOR THE FUTURE

Most exciting, perhaps, are those experiments which will employ the manned plastic balloon vehicle and its demonstrated stability as a laboratory for definitive astrophysical measurements. The system now under development by Prof. John Strong will allow the first significant evaluation of this high-altitude capability from a manned plastic balloon. His system—which

employs a Schmidt telescope with 16-in. primary mirror, a special spectrograph, and an automatic tracking device—will be manually oriented from the gondola to a position where it will "lock on." During subsequent exposures of an hour or more Dr. Strong or his flight representative will manually "trim" the image with a clever monocentric mirror system.

It is planned to begin this fascinating new exploration when Mars again approaches the earth in November of this year with two Strato-Lab night flights. During one, it is hoped to make measurements of water vapor in the Martian atmosphere; during the other, a determination will be made of the oxygen content. It is also hoped to acquire solar information during the daytime portions of the flights.

If the Strong experiments are as revealing as expected, an entire new vista will be opened for further astrophysical research from the manned plastic balloon observatory.

In the area of human factors studies related to men in space, it is recognized that weightlessness is merely one factor which cannot be simulated with a stratospheric balloon gondola. Most factors, however, can be. Extended duration flights, therefore, are being considered with crews of varying numbers. These would allow evaluation, in a real situation, of special artificial environments designed and ground tested for future manned satellites.

The radiobiological effects of cosmic radiation will be another hazard encountered by future astronauts. In view of Schaefer's indications that altitudes of 132,000 ft. are necessary to study the problem properly, a severe problem is presented for a manned balloon system to assist. The capability does not exist today, and it is likely near the practical limit of a manned balloon system. Recent unmanned Skyhook flights to altitudes as high as 138,000 ft. (and one remarkable flight to 145,000 ft.) give promise, however, to approaching the goal of 132,000 ft. in the future.

Conclusion

The manned balloon laboratory concept can be an important stepping stone, or "bridge" as first suggested by Moore,[31] to manned earth satellites and space ships. Certainly it is not a space vehicle. There are a number of dissimilarities. The phenomenon of weightlessness is merely one. But, in many important aspects related to the occupants, a sealed cabin suspended from a stratospheric balloon is remarkably comparable to future sealed cabins in orbital vehicles. The flights and tests conducted to date can be extended to answer knotty problems facing the scientists and engineers who will design and build true space cabins in the not-too-distant future.

Exploration of the space environment can also be conducted from the manned balloon vehicle, floating above most of the earth's atmosphere, with an appropriate sealed cabin observatory from which astronomers and astrophysicists can search the realm of space. The rewards from these investigations should be tremendously important.

Scientists and engineers are urged to give serious thought to future information needs and consider manned balloons as tools to supply the answers.

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(*Continued on page 56*)

"Spares programs frequently meet with resistance simply because their far-reaching effects are not normally understood by engineering and manufacturing people until it is too late to aid the program."

Spares for Weapons Systems

Louis P. Stannard
Hughes Aircraft Company

ALTHOUGH THE NEED for spare parts has existed since the birth of manufacturing, the term "spare" has achieved truly gold-plated significance in this the Electronics Revolution.

The evolution of weapons systems, which may virtually eliminate man from any direct participation in aerial warfare, has projected the term "reliability" into irrefutable view. These systems, in order to justify their high cost, must function automatically with speed and accuracy far in excess of man's capabilities, as extended by mechanical devices. In addition, equipment must be sufficiently reliable to perform successfully during long periods of operation. A single failure, no matter how small, cannot be compensated for by man during the operating cycle. This could spell the end to a disastrous mission.

The reliability of any piece of equipment is proportional to the application of four fundamentals: (1) design, (2) material, (3) production quality control, and (4) maintenance quality control. The degree of application of each of these fundamentals has direct influence on spares requirements, yet spares programs frequently meet with resistance simply because their far-reaching effects are not normally understood by engineering and manufacturing people until it is too late to aid the program.

It is generally known that approximately two-thirds of the failures experienced by electromechanical equipment are directly attributable to the electronic components within that equipment. Many of these failures are precipitated by standard commercial parts because of their inherent limitations. Equipment failures, however, are laid upon the prime contractor's door step. It follows, then, that spares requirements must be kept at a minimum or manufacturers may suffer the consequences in cancelled contracts and tarnished reputations. However, the most obvious, the simplest, and probably the most acceptable method of lowering spares requirements is via increased reliability. Under-support may cause a catastrophe; over-support is merely expensive. It goes back to the old story, "For want of a nail ...." A recent illustration of this was the grounding of an $8,000,000 bomber because of failure in a small repairable subassembly for which a replacement part was not available.

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CONCURRENCY

The first and possibly the most significant step which any company can take upon receipt of a government contract is to assemble the "big four" (Engineering, Manufacturing, Contracts and Spares Groups) to recite their marriage vows. A kissing cousin relationship between these departments is not good enough and may jeopardize the spares program.

The most important support requirement, which can only be accomplished by joint effort, is the concurrent delivery of spares with the end item or system. This is mandatory to provide adequate spare quantities at any point in time. In order to achieve concurrent delivery, it is necessary to establish (1) planning—resulting in realistic manufacturing and delivery schedules: (2) engineering which is timely in execution and feasible in application for both manufacturing and spares exigencies; (3) manufacturing processes which, even when altered, do not throw the spares program out of phase; and (4) a paper mill which is sufficiently streamlined to prevent a shipping or manufacturing bottle-neck.

All of these, when properly established, mean tremendous cost savings, not the least of which is a reduction in the ratio of spares dollars to equipment dollars. Obscure as it may seem, reliability will be enhanced because of a tight big four relationship. An illustration of poor coordination between spares and manufacturing is the following: Manufacturing, having completed the production phase and unaware of spares requirements, detools and cleans up in preparation for another project. At this time a spares order is received, necessitating re-

tooling and building of a new production line. Not only is needless cost entailed, but the spares program is thrown completely out of concurrency, a situation which may never be rectified during the entire span of a contract.

Contracts

Generally, there are three types of contracts which are administered successively in this order: (1) research and development, (2) technical training, and (3) production. Normally, only training and production programs require spares support, since research and development concerns the evolution of various conceivable prototypes under government auspices.

Although a company may be working under a production contract, very important research and development and training programs may also be included under separate items of the contract. Concurrent research and development programs for guided missiles, for instance, supply failure information through telemetry while missiles are in flight. Appropriate design improvements may then be expeditiously incorporated in production missiles.

Training, of course, must be perpetually conducted because of the current high turnover rate among service maintenance personnel and because of the inevitable newness of the equipment brought about by engineering changes.

Cost and Profit

In consideration of costs, the ratio of spares dollars to equipment dollars may vary from 5 per cent to more than 100 per cent. The reasons for this include: (1) variations in the quantities of systems to be supported (programs involving small quantities of systems must still receive a certain minimum of support; in some cases, support figures indicate that less than one each of a given part would be required, but these would have to be rounded off to one, thus raising the percentage); (2) variations in support periods (some programs have a duration of 6 months, other may run 5 years); (3) types of equipment supported (guided missiles require less support than airframes which require less support than fire control systems); (4) the frequency of operation (fire control systems and airframes may operate every day; missiles are expendable items receiving simulated operation and periodic checks only prior to firing); (5) the type of operation (including training and combat under various environmental influences); and (6) whether a basic follow-on contract is supported (where design improvements have reduced attrition).

More specifically, training programs almost invariably require spares in excess of 100 per cent of equipment costs. Every-day operation of equipment over an extended period of time by personnel undergoing training is bound to require great quantities of spares. These training items are likely to be used for years, until they virtually fall apart.

Basic production contracts for guided missiles should require spares equivalent to 15 per cent or 20 per cent of equipment costs. However, production follow-on contracts, incorporating design improvements, may show a decrease to as little as 5 per cent for spares. On the other hand, simple fire control systems initially require about 40 per cent for spares while complex systems reach 80 per cent. These percentages also diminish for follow-on contracts.

Being largely structural, aircraft require a small percentage of spares during the early stages of support. However, over a period of 5 or 10 years, spares costs may exceed the aircraft cost many times over. Another consideration, which is simple and logical—as the design is improved and production increased, costs will drop substantially, even though the ratio of spares to equipment dollars may remain unchanged.

Profits from Government contracts negotiated under the Vinson-Trammell Act or the Renegotiation Act of 1951 vary with the configuration of the equipment, the stage of its development, and with the type of contract (CPFF, FP, FPI etc.).

Lead Time

Production lead time is a mandatory consideration for the assurance of concurrent delivery of spares with the equipment to be supported. Lead time requirements vary considerably from company to company, depending upon the size of the company, type of equipment produced, quantities of the equipment required for initial delivery, and the efficiency of the manufacturing facility. Actual lead time requirements could vary from a minimum of 2 months to a maximum of 2 years. This means that spares recommendations must be submitted to the customer and subsequently approved, in many instances, prior to the issuance of firm production engineering. These recommendations are then subjected to a great deal of manipulation as engineering nears the production stage. Lead time requirements should experience a continual drop as the program progresses and production lines reach full capacity.

Vendor Equipment

Government procurement agencies for the armed forces require provisioning documents and technical data for repairable vendor equipment. Under these circumstances it is necessary for the prime contractor to coordinate with the appropriate vendors expeditiously, in order to provide spares recommendations in time for the provisioning conference.

Many vendors, particularly the small specialty manufacturers, have never produced articles for government use, or at least have not been approached regarding a spares program. As a result, the prime contractor must instruct vendor personnel in the preparation of provisioning documents required by federal specifications covering prime contracts.

Frequently, personnel, equipment, and space limitations prevent the vendor from preparing these documents. The alternative is that the prime contractor

must obtain all the requisite technical data and prepare the documents at the home facility.

Unique design or construction may remove a vendor assembly from government depot repairability. This is generally undesirable because shipping distance and repair time increase markedly. In addition, the vendor must set up facilities and divert or hire personnel for the sole purpose of repairing defective equipment.

The vendor's ability to adjust to the requirements of a spares program will not only affect his profits from spares sales but also will enhance his "bidding" position.

High Value Items

"High value items" are designated during customer contractor negotiations when the ratio of part to equipment cost is high or when the failure tendency of a part is high enough to warrant a large support quantity (also causing high cost). Certain high cost items may not be designated high value because their attrition is very low. By the same token, most high attrition items are not designated high value because their individual cost is low. The result is that a compact list of high value items is available for accounting purposes to control what amounts to approximately 5 per cent of the spares quantity-wise but 75 per cent of the spares cost-wise. High value parts are also serialized to aid cost control.

Field or Depot

Field and depot requirements vary substantially with the type of equipment supported. Fire control systems, for example, are for the most part field repairable; guided missiles, on the other hand, may only receive unit replacement in the field, while the bulk of maintenance is performed in the depot. (Unit is defined as any major assembly used in a piece of equipment, having a unique function but working in conjunction with other such assemblies.) This is true because at the present stage of development missile designs are still tricky. Also, the obtuse conditions of atmosphere, acceleration, and vibration during flight require many assemblies to be sealed and evacuated to perform adequately. As a consequence, special tools and equipment and complex repair techniques are necessary, eliminating field maintenance as a possibility. Still, as empirical data is accumulated and design requirements are relaxed, an increasing variety of maintenance operations will be performed in the field. The ultimate goal, of course, is to make all equipment completely repairable in the field.

Field engineers are key figures in the spares picture. Not only do they keep government maintenance personnel abreast of repair techniques as designs change, but they have first-hand information concerning the kinds and frequencies of failures under normal operating conditions, which is submitted to the contractor in the form of unsatisfactory reports, or in conjunction with them. They also establish the requirements for special tools as determined during field maintenance and to a high degree control the varieties of field repair performed.

Maintenance Turn-Around-Time

Turn-around-time is the period required to transport a defective unit to the depot, perform the necessary repairs, and return it to squadron use (field). Turn-around-time is a grave factor in spares costs because small variations in turn-around-time cause large variations in cost. Spare units are stored in small quantities at the squadron level, while the bulk of them are placed in pools at the storage facility. This arrangement satisfies emergency situations where a given squadron, because of abnormal attrition, runs out of replacement units. The pool may then furnish necessary replacement units much more expeditiously than the process of querying individual squadrons and establishing shipment would allow.

When a unit becomes defective, the using squadron simply telegraphs for a new one, which is shipped at the same time that the defective unit is returned to the depot. This eliminates delay during the repair cycle. The depot repairs the unit, which is enhanced by replacement of the defective subassembly (or rotatable spare), if applicable, rather than attempting to repair the subassembly on the spot. The unit is then returned to the pool and depot personnel are able to repair the defective subassembly at their convenience.

Shelf Life

Shelf life is an important consideration to the recommendation of spares quantities. Rubber goods and plastics, particularly, are affected by the environmental conditions of storage, which may be more injurious than continued use. The result of this is that at intervals determined by shelf life investigations, assemblies which have been in storage in excess of the established period will be overhauled and all items attritionable through shelf life, replaced. Unfortunately, the shelf life of a particular material may be long when used in one assembly and short when used in another. If these parts operate under fluids, their life expectancy will vary with the deteriorative effects of the fluids. Consequently, spare unit recommendations must be increased to provide replacements for units returned for shelf life overhaul, over and above those necessary for normal repair. Also, spares quantities must be increased accordingly for small bit and piece parts replaced during shelf life overhaul.

Recommending Spares

The recommendation of spares entails consideration of what seems to be an infinite number of variables. Naturally, it is impossible to detect every factor, just as it is impractical to apply many known factors. Even so, derivation of spare quantities which will prove to be very close to actual requirements may be expected,

providing the following considerations are made: (1) the failure factor of the part; (2) the number of anticipated failures of the using unit; (3) usage of the part within the unit; (4) length of the support period; (5) kind of equipment supported; (6) the amount and kind of usage to which the equipment will be subjected; (7) shelf life requirements; (8) turn-around-time; (9) the number of end items or systems to be supported; and (10) the maintenance level of the part (field, depot or vendor).

It may be difficult to recommend accurate spares quantities during initial contracts for equipment which is either completely new in concept or at least new to the company producing it. There is little "feel" for failure tendencies and no empirical data to substantiate recommendations. However, when a program progresses to the point where accurate consumption reports are submitted by repair facilities, the process of recommending spares is simplified. Instead of basing recommendations on *anticipated* failures, it is then possible to utilize *actual* failures.

Provisioning

Preprovisioning and provisioning conferences between contractor and customer put the spares program "on the road." Preprovisioning conferences serve to establish provisioning procedures, documentation requirements, support periods, design change notification methods, field and depot requirements, etc.

At the time of the provisioning conference, the contractor must submit recommended quantities for parts which he considers good spares. The customer, having previously received provisioning documents indicating recommended spares, must inventory his bin levels for all applicable commercial standard and contractor peculiar parts purchased under other contracts. The customer and contractor review the provisioning document to confirm or alter the status of all parts with respect to provisionability.

The minutes of the conference reflect all agreements made and discrepancies to be corrected. Before leaving, the customer normally submits a "buy" to the contractor for all parts considered good spares. This buy should closely follow the recommendations made by the contractor, if all has gone well. The buy is then fully documented as a spare-parts list.

Engineering changes, made to the equipment after the buy, are submitted for customer approval under the previously agreed upon design change notification method. Spares quantities for old parts are prorated with those for new parts as engineering changes are released.

The customer continually reviews his requirements, which are augmented by consumption reports indicating actual attrition and may alter procurement for certain parts to bring the support quantities in line with these reports. These changes are routine throughout documentation of the spares program.

✦ ✦ ✦

Manned Balloons in the Exploration of Space (Continued from page 52)

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Acoustics, Sound, Noise

Neposredstvennoe Nabliudenie Iskazheniia Formy Intensivnykh Ul'trazvukovykh Voln v Zhidkosti. V. A. Burov and V. A. Krasil'nikov. *AN SSSR Dokl.*, Feb. 11, 1958, pp. 920–923. In Russian. Presentation of direct observations of the distortion of intense supersonic waves in a liquid.

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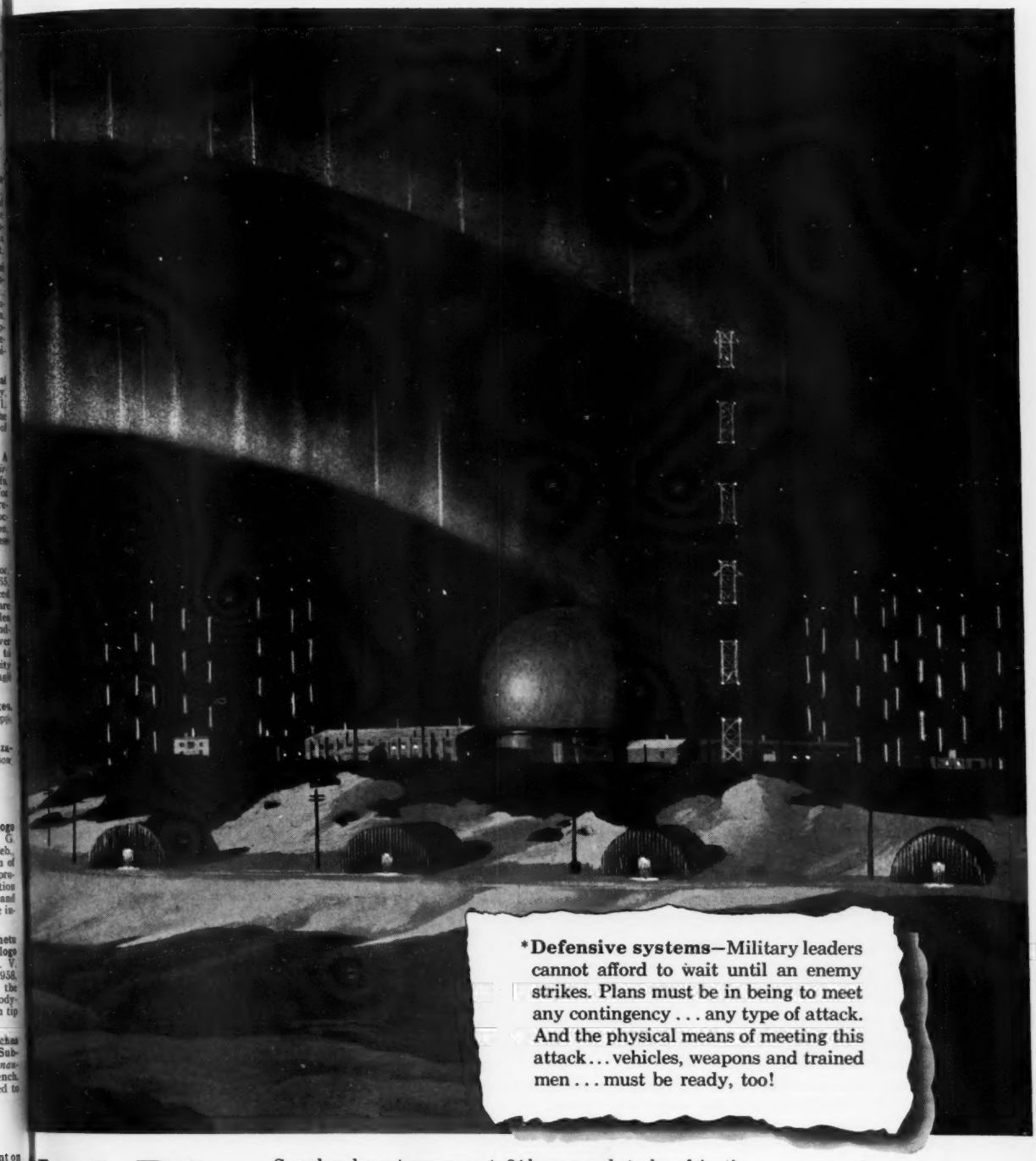

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I—Douglas Uses Extra Time to Refine DC-8 for Jet Race. II—Safety Dominates DC-8 Jet-

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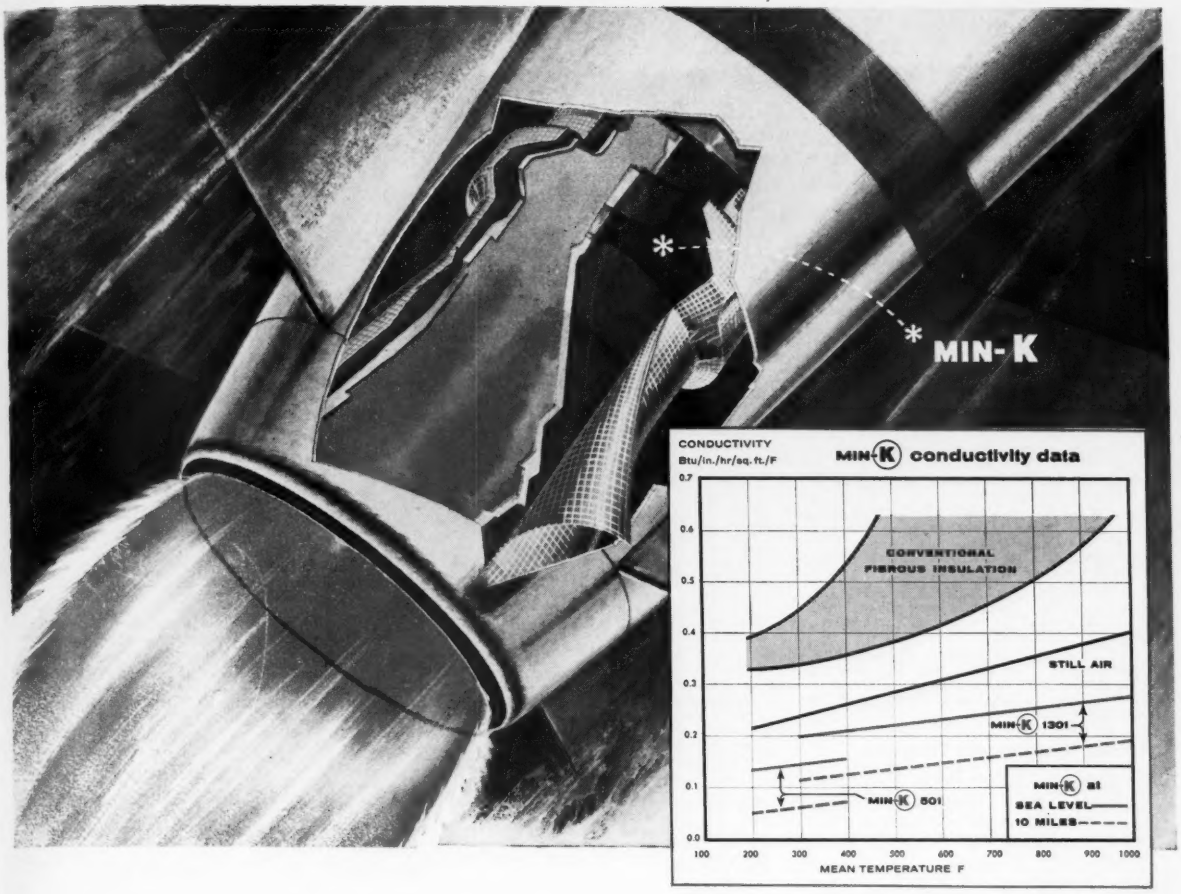

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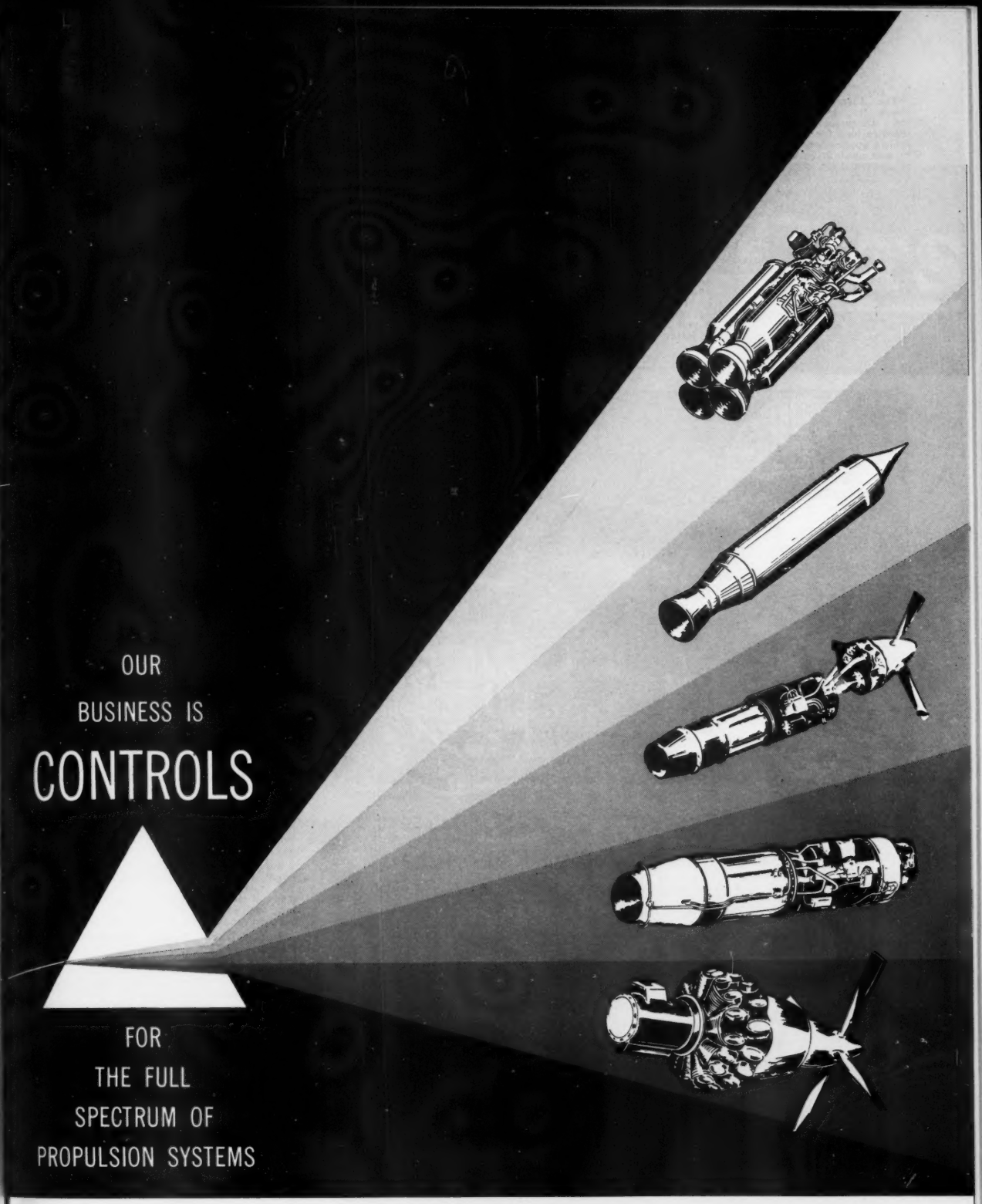

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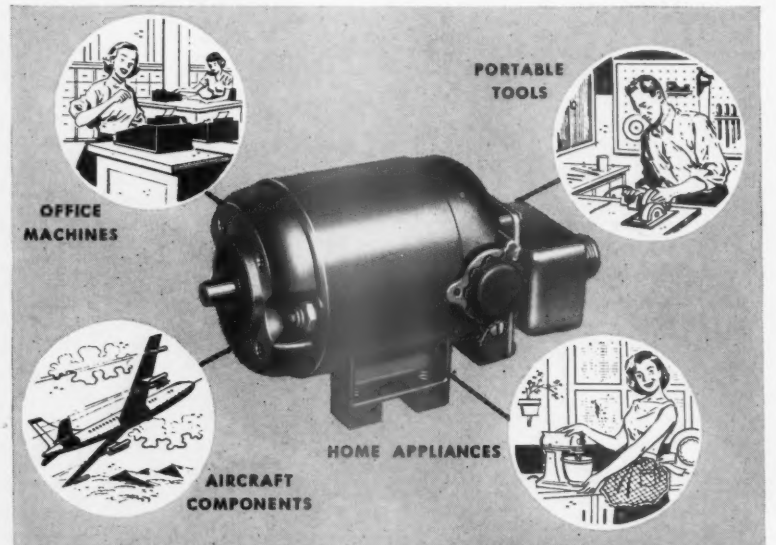

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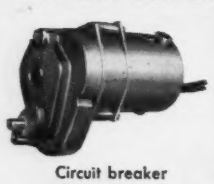

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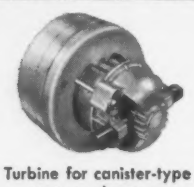

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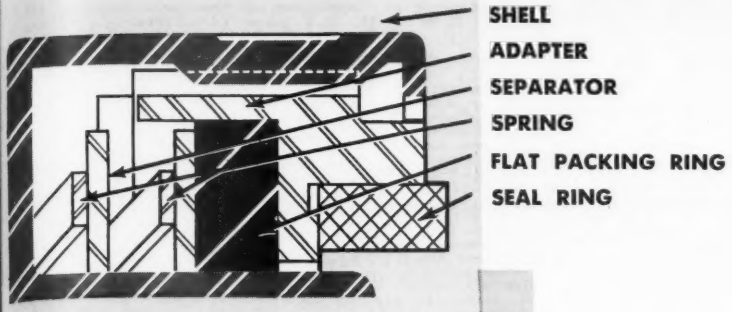

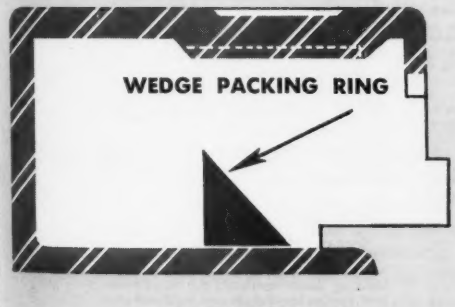

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Dielectrics

A Property of Dielectric Constants of Dielectrics in Thermal Equilibrium. Martin Peter. *J. Math. & Phys.*, Jan., 1958, pp. 347–350. USAF, Army-Navy-supported analysis of the dielectric constant for the case where the dielectric is dispersive and passive. A lumped model circuit of equilibrium dielectric constants is built.

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New Breed of Microwave Tubes Spurs Radar, ECM, Scatter Designs. James Holahan. *Av. Age*, Apr., 1958, pp. 22, 23, 156–158, 160–164. Description of forward and backward type microwave tubes. A tabular representation of their main characteristics is made.

Transistor Circuits for Use with Gas-Filled Multi-Cathode Counter Valves. J. B. Warman. *Electronic Eng.*, Mar., 1958, pp. 136–139. Presentation of a technique which enables complex digital circuits using both transistors and Dekatrons to operate from a low-voltage power supply.

Magnetic Devices

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Applications of Non-Linear Magnetics. I. H. F. Storm. *Electronic Des.*, Feb., 19, 1958, pp. 32–35. 22 refs. Description of the design, operation, and applications of the saturable core device alone and in combination with other circuit elements.

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DC Transformer Has Continuous Adjustable Ratio. H. E. Darling. *Electronic Des.*, Mar. 5, 1958, pp. 40–43.

Measurement & Testing

Rapid Testing of Tube Shorts and Continuity. *Electronic Des.*, Mar. 19, 1958, pp. 36–39.

Some Methods of Phase Measurement Used in Transfer Function Analysis. D. J. Collins and J. E. Smith. *Electronic Eng.*, Apr., 1958, pp. 182–186.

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Networks, Filters

VHF Matching Network Design. A. E. Sanderson. *Electronic Des.*, Mar. 19, 1958, pp. 20–23.

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How to Correct Phase Distortion with an L-C Lattice. J. D. Fogarty. *Electronic Des.*, Apr. 2, 1958, pp. 20–23.

Noise, Interference

Atmospheric Radio Noise; Equipment for the Measurement of Amplitude Distributions. J. Harwood and C. Nicolson. *Electronic & Radio Engr.*, May, 1958, pp. 183–190.

Detection of Pulsed Signals in Noise; Optimum Butterworth Third-Order Filters. H. S. Heaps and A. T. Isaacs. *Electronic & Radio Engr.*, May, 1958, pp. 190–193.

A Tunable Filter for Use in the Measurement of Excess Noise from Local Oscillators. W. P. N. Court. *Electronic Eng.*, Apr., 1958, pp. 208, 209.

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Oscillators, Signal Generators

Maser Is Here. *Electronic Des.*, Mar. 19, 1958, pp. 24, 25. Presentation of design characteristics and applications of the Maser oscillator.

Piezoelectricity

Scanners for Ferroelectric Memory Capacitors. C. F. Pulvari and G. E. McDuffie, Jr. *IRE Trans., EC Ser.*, Mar., 1958, pp. 34–40. USAF-supported study.

Power Supplies

Radio Waves Power Transistor Circuits. L. R. Crump. *Electronics*, May 9, 1958, pp. 63–65. Discussion of a system which derives all power required to operate various types of transistor circuits from electromagnetic energy radiated by distant sources.

Optimum Design of Power Transformers and Saturable Reactors. I, II. T. R. Nisbet. *Electronic Des.*, Apr. 16; May 28, 1958, pp. 26–29; 48–51. General design procedure for optimizing flux density and window shape.

Improved Power Fault Protection. J. T. Mark. *Electronic Des.*, Mar. 5, 1958, pp. 46–49. Description of a simple high-speed fault-protection circuit which provides both dump tube and rectifier-blocking protection.

400-Cycle Inverter Is Transient-Proof. G. M. Ford. *Av. Age*, May, 1958, pp. 150–152. Description of a device used as a voltage regulator and power converter.

Radar

Recent Developments in Radar. L. M. Barker. *Astronautics*, May, 1958, pp. 28, 29, 67, 68. Discussion of modern trends in radar development for search and tracking purposes, and for radio-inertial command guidance.

How to Minimize Radar Effects on Electronic Circuits. W. G. Egan. *Electronic Des.*, Mar. 19, 1958, pp. 52–55.

Reliability

Design for Reliability. *Electronic Des.*, Feb. 19, 1958, pp. 1–23. 16 refs. Discussion of the status of reliability of electronic equipment, including some methods for predicting reliability and guides for circuit and equipment design.

Reliability-Sensitivity-Function Analysis. H. E. Blanton. *Electronic Des.*, Feb. 19, 1958, pp. 22–25. Analysis providing an approach to the quantitative evaluation of the rate of change of system reliability with respect to changes in the reliability of the particular part.

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INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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ACOUSTICS, SOUND, NOISE

RESEARCH ON INVESTIGATION OF THE INTERACTION OF SOUND AND TURBULENCE. W. Tollmien. Max Planck Inst. Rep. (EOARDC TN 58-236) [AD154138], Mar., 1958. 34 pp. Investigation of the elementary processes of scattering of sound by a vortex, and of the dependence of the scattering properties on the characteristic parameters of the problem. A superposition is made of the effects of elementary scattering in a field of flow in which the vortices are statistically distributed due to an arbitrarily given distribution function controlling direction of the axis, size, and circulation of the vortices. The basic equations will be Euler's equations of motion and the equation of continuity. The influence of friction and heat conduction are neglected. The method of small disturbances is used to obtain a solution; all properties in the field of motion are developed in a power series of a small parameter, in this case the amplitude of the sound oscillations.

ON THE STRENGTH DISTRIBUTION OF NOISE SOURCES ALONG A JET. H. S. Ribner. UTIA Rep. 51, Apr., 1958. 26 pp. 15 refs. AFOSR-supported investigation of the spatial distribution of noise sources along a jet by application of Lighthill's theory to regions of "similar profiles." The analysis refers to the noise power emitted by a "slice" of jet (section between two adjacent planes normal to the axis) as a function of distance x of the slice from the nozzle. Because of the striking attenuation of strength with distance, it is concluded that the mixing region produces the bulk of the noise and must dominate in muffler behavior; conversely, the "fat" part of the jet must contribute much less to the total noise power than is commonly supposed. Powell's experiments on the effects of nozzle velocity profile on total noise power are interpreted qualitatively. The behavior of multiple-nozzle or corrugated mufflers, both as to overall quieting and frequency-shifting, is also interpreted in the light of the results.

SOME MEASUREMENTS BEARING ON THE PRINCIPLE OF OPERATION OF JET SILENCING DEVICES. Appendix I - ON THE MEASUREMENT OF THE NOISE SOURCE STRENGTH. Appendix II - APPROXIMATE RELATIONS BETWEEN LOW SPEED TURBULENCE AND NOISE. G. M. Corcos. Douglas Rep. SM-23114, Mar., 1958. 39 pp. Theoretical and experimental investigation to explain in simple terms how ejectors, corrugated nozzles, and multiple nozzles modify the turbulent mixing of a jet so as to generate less aerodynamic noise. These types are shown to have less aerodynamic noise than corresponding plain nozzles because they decrease the turbulence levels in the mixing region. This is accomplished by accelerating the ambient air before it is mixed with the jet. Thus, a sheath of flowing air decreases the lateral jump in the mean axial velocity which is responsible for the turbulence level in the mixing region. Experiments at low speed with corrugated nozzles and ejectors are then reported. Mean velocity profiles and turbulence surveys are obtained. The results are in good agreement with the expectations and provide strong support for the hypothesis.

GROUND REFLECTION OF JET NOISE. Appendix A, B - INDICATED SOUND-PRESSURE-LEVEL SPECTRA. Appendix C - AUTOCORRELATION COEFFICIENT. W. L. Howes. US, NACA TN 4260, Apr., 1958. 56 pp. 12 refs. Theoretical and experimental investigation on the effect of the reflecting plane on the propagation of jet noise. From the theoretical characteristics of far-field acoustic decay a correction-to-free-field procedure is developed for data obtained in the presence of a plane. Measurements of jet noise indicated the practical significance of reflections. Several theoretical predictions were confirmed from experimental decay curves and corrected spectra.

METHODES D'INSONORISATION DES AVIONS DE TRANSPORT ET SPECIALEMENT DU BIREACTEUR S. E. 210 CARAVELLE. M. Kobrynski. La Recherche Aéronautique, Mar.-Apr., 1958, pp.

33-39. 10 refs. In French. Description of methods for the acoustical insulation of transport aircraft and particularly the twin jet S. E. 210 Caravelle. Noise levels for cruising flight of several aircraft types are given graphically for forward and aft zones of the cabin, and frequency spectra of piston, turbojet, and turboprop power plants are compared. Includes evaluation of the engine position and weight considerations.

ACOUSTIC, THRUST, AND DRAG CHARACTERISTICS OF SEVERAL FULL-SCALE NOISE SUPPRESSORS FOR TURBOJET ENGINES. C. C. Ciepluch, W. J. North, W. D. Coles, and R. J. Antl. US, NACA TN 4261, Apr., 1958. 48 pp. 10 refs. Experimental investigation of turbojet-exhaust noise suppressors on nonafterburning engines of the 10,000-pound-thrust class. Acoustic measurements were made around an outdoor thrust stand. Thrust and drag measurements were obtained over a range of flight speeds and altitudes in the Lewis altitude wind tunnel. Results indicate that, during aircraft take off, the peak noise levels from the 12-lobe and ejector mixing nozzles are the lowest; the observed levels being 5 to 6 decibels less than those attained with the standard nozzle. Up to a flight Mach Number of 0.5, most of the decrease in propulsive thrust results primarily from internal thrust losses.

AERODYNAMICS

Aerothermodynamics

ON THE AERODYNAMIC HEATING OF BLUNT BODIES. E. R. van Driest. North Am. Av. MD 58-6 (AFOSR TN 57-732) [AD 136716], Nov. 1, 1957. 31 pp. 10 refs. Calculation of the heating rate for blunt bodies in high-speed flight, and discussion of the phenomenon of transition. An analysis of the problem with transpiration cooling is presented, and mass transfer as a means of alleviating turbulent heating is described. Observations of velocity data near the wall of a pipe indicate that an inner stability region exists adjacent to the wall where the turbulent eddies and Reynolds stresses alter the laminar velocity profile. The inner viscous region decreases strongly with cooling. It is shown that the analysis of heat transfer for turbulent flow with blowing or suction reduces to the problem of joining the laminar sublayer and the fully turbulent zone. The friction and heat transfer coefficients for flat plates, spheres, and cylinders are calculated. The ratios of the friction and heat-transfer coefficients with mass transfer to those without mass transfer for the flat plate are given in graphical form along with the stagnation region of the sphere and the cylinder.

LAMINAR HEAT TRANSFER ON BLUNT-NOSED BODIES IN THREE-DIMENSIONAL HYPERSONIC FLOW. R. Vaglio-Laurin. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech. TR (AFWADC TN 58-147) [AD 155588], May, 1958. 29 pp. Analytical considerations and comparisons with known exact solutions indicate that in the presence of highly cooled surfaces and of moderate outer flow Mach Numbers the crossflow in the boundary layer is negligible even for large transversal pressure gradients. From this a rapid method for estimating the heat transfer over the nose portion of arbitrary three-dimensional blunt bodies in hypersonic flight is derived. This method reduces the boundary-layer problem to the determination of the inviscid streamline pattern on the surface of the body; a procedure for obtaining these streamlines from a pressure distribution measurement is outlined.

EVAPORATION INTO A BOUNDARY LAYER. Ernest Bauer and Martin Zlotnick. Avco Res. & Adv. Devel. Div., RAD U-58-14, May 7, 1958. 6 pp. Determination of the evaporation rate of a solid (or liquid) evaporating into a stream of gas flowing across its surface. Chemical reactions are neglected. The processes of evaporation and diffusion are considered in turn. It is shown that at the surface there is no x-component of drift velocity; therefore, convection in the x-direction is not considered. An approximate numerical estimate of the relative humidity is obtained. The immediate application is to the problem of aerodynamic heat transfer in hypersonic flight.

THE CALCULATION OF THE WALL TEMPERATURE ALONG SURFACES WHICH ARE EXPOSED TO A FLUID STREAM WHEN THE LOCAL HEAT FLOW THROUGH THE SURFACES IS PRESCRIBED. E. R. G. Eckert, J. P. Hartnett, and Roland Birkebak. USAF WADC TR 57-315 [AD 118333], May, 1957. 24 pp. Presentation of a method applicable to either laminar or turbulent boundary layer flow with zero pressure gradient. Calculation procedures are shown for several heat rate distributions.

THE INTERACTION OF SHOCK WAVES WITH SMALL PERTURBATIONS. I, II. S. P. D'iakov. (Zhurnal Teoret. i Exper. Fiz., Oct., 1957, pp. 948-974.) Sov. Phys.-JETP, Apr., 1958, pp. 729-749. Translation. Analysis within the framework of the two-dimensional stationary problem in which the flow behind the shock is considered as supersonic in the first case and subsonic in the second case. In the first case the general results are applied to the study of the interaction with weak discontinuities, weak shock waves, and with the interface between two media of slightly different acoustical properties. In the second case a solution is given for the interaction of weak and weak-tangential discontinuities with the shock wave. In both subsonic cases the weak-tangential discontinuity formed behind the shock wave possesses a specific logarithmic discontinuity.

ON MASS TRANSFER NEAR THE STAGNATION POINT. E. R. van Driest. North Am. Av. Missile Devel. Div. Rep. AL-2553 (AFOSR TN 57-458) [AD 136449], June 1, 1957. 20 pp. Computation of heat transfer with blowing near the stagnation point by analyzing the problem for the flat plate without pressure gradient and converting the solution to that for the stagnation region of spheres and cylinders; assuming incompressible flow. The friction on a flat plate is obtained from the momentum inte-

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gral taking into account mass transfer. The velocity profile is approximated in order to facilitate integration. The local friction and heat transfer coefficients are plotted. A graphical representation of the ratios of the friction and heat-transfer coefficients with mass transfer to those without mass transfer for the flat plate, the stagnation region of the sphere, and the cylinder is given.

Flow of Fluids

COMPRESSIBLE FLUIDS IN STEADY TWO-DIMENSIONAL SUBSONIC FLOW. G. Power and P. Smith. Appl. Sci. Res., Sect. A, No. 5, 1958, pp. 357-368. Analysis of adiabatic flow past a large number of profiles, which can be obtained as accurately as desired, even when approaching sonic speed, by considering the correct differential equations for steady two-dimensional subsonic flow and making successive approximations to their solutions. Examples are given and results compared with those obtained by other means. A way of constructing channels suitable for subsonic flow at high speed is also indicated. Finally a method of estimation by upper and lower bounds is suggested.

FONCTIONS THETAELLIPTIQUES ET DZETA-ELLIPTIQUES; APPLICATION AU CALCUL DE L'ECOULEMENT AUTOUR DE L'AILE CONIQUE. Robert Legendre. France, ONERA Pub. 91, 1958. 73 pp. In French. Definition of theta- and zeta-elliptic functions and application to the calculation of flow around thin conical wings in uniform supersonic flow. The definition and the study of properties of elliptical functions and integrals are performed without the use of Jacobi or Weierstrass functions in order to model the process of calculation according to that used for rational integrals.

APPROXIMATE METHOD FOR CALCULATION OF OGIVE-CYLINDER AERODYNAMIC CHARACTERISTICS. F. W. Fenter. (Quart. Rev. Bumblebee Activ., Jan.-Mar., Apr.-June, 1957.) Johns Hopkins U., APL BB Rep. 270, 1958, pp. 23-29. Derivation and substantiation of a new approximate method applicable to a large class of aerodynamic body contours. The correction procedure used extends the applicability of the generalized shock-expansion method. Accuracy and reliability of the developed formulas are determined by comparing aerodynamic characteristics computed by this new method with the "exact" solution computed by the method of characteristics. It is concluded that the new approximate method is numerically simpler and more accurate than other known approximate methods. It enables pressure distributions on nonlifting ogive-cylinders to be calculated accurately over a wide range of Mach Numbers and ogive fineness ratios.

THE PRESSURE DRAG DUE TO TURBULENT SEPARATION ON BODIES OF REVOLUTION WITH VARYING BOUNDARY LAYER THICKNESS. E.G. M. Petersohn. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 75, 1957. 9 pp. Investigation of the effect of the boundary layer thickness on the flow separation over the rear portion of bodies of revolution by pressure measurements. A reduction of the boundary layer thickness was obtained by reducing the length of the turbulent region. A description of the models and the testing procedure is made. Results indicate that the pressure drag due to flow separation is independent of the Reynolds Number. For slender bodies there seems to exist a tendency for the pressure drag to decrease with decreasing boundary layer thickness. For less slender tails with strong separation, the latter tendency can hardly be traced.

EXACT SOLUTION OF THE NEUMANN PROBLEM; CALCULATION OF NON-CIRCULATORY PLANE AND AXIALLY SYMMETRIC FLOWS ABOUT OR WITHIN ARBITRARY BOUNDARIES. A. M. O. Smith and Jesse Pierce. Douglas Rep. ES-26988, Apr. 25, 1958. 106 pp. 28 refs. Development of a general method for solving the Neumann or second boundary-value problem, and application of the method to the calculation of low-speed flows about or within bodies of almost any shape, provided the flow is either plane or has axial symmetry. The method is capable of dealing with several bodies at once in the presence of another, and consequently interference problem can be treated with ease. Boundaries need not be solid - i.e., flow involving area suction can be calculated. Velocities can be computed not only for points on the surface of the body but for the entire flow field. A surface source distribution is used as the basis for the solution. This leads to a Fredholm integral equation of the second kind which is solved as a set of algebraic equations, usually by a modified Seidel method. The solution is programmed on the IBM 704 EDPM to solve the flow about any body that has the previously mentioned characteristics and whose profile can be defined by no more than 300 coordinate points.

ON THE HYDRODYNAMIC STABILITY OF CURVED LAMINAR FLOWS. M. Lessen. ZAMM, Mar.-Apr., 1958, pp. 95-99. AFOSR-supported investigation of the stability of curved laminar compressible flows indicating that, under certain conditions, instabilities can exist in the flow field around bodies moving at high speed. The general disturbance equations are derived, and some simplified cases are discussed. Factors influencing stability are pointed out for both compressible and incompressible cases.

ON SOME FUNDAMENTALS IN MAGNETO-FLUID-MECHANICS. E. E. Covert. MIT NSL TR 247, Mar., 1958. 300 pp. 94 refs. Derivation of the basic equations of magneto-fluid-mechanics from kinetic theory for a gas consisting of neutral particles, positive particles, and electrons. These equations are normalized, and the characteristic parameters are illustrated. The fluid properties are calculated, and a summary of their values is given. Some examples of elementary magneto-fluid mechanical flows are given to illustrate the basic behavior of these flows. The problem of adding energy to a gas by magneto-fluid mechanical means is discussed and it is concluded that these means are practical only at high power densities.

A device which absorbs such power densities and generates a plasma is discussed theoretically, and some preliminary experimental results from this device are given.

COMBUSTION OF A GAS INJECTED INTO A HYPERSONIC LAMINAR BOUNDARY LAYER (Aerophysics Research Memo No. 9). G. W. Sutton. G-E MOSD TIS R58SD218, Jan., 1958. 29 pp. Analysis of the structure of a laminar boundary layer at a stagnation point of a blunt-nosed body traveling at hypersonic velocities in air for the case of area mass transfer cooling with combustible gas. The continuity, momentum, energy, and diffusion equations are simplified in accordance with the usual assumptions. The temperature and local mass fractions are shown to be linear in the tangential component of velocity, except at the reaction zone. Results indicate that for small injection rates, the use of a combustible gas may lead to temperatures which are higher than the recovery temperature of the flow. With increasing injection rates, the flame front is removed from the surface and the wall temperature decreases. A comparison of results to the case of injection of a noncombustible gas is made. It is shown that more combustible than noncombustible gas is required to maintain a given wall temperature, but the percentage decreases as the ratio of wall temperature to recovery temperature decreases.

MEASUREMENT OF THE EFFECT OF AN AXIAL MAGNETIC FIELD ON THE REYNOLDS NUMBER OF TRANSITION IN MERCURY FLOWING THROUGH A GLASS TUBE. Michel Bader and W. C. A. Carlson. US, NACA TN 4274, May, 1958. 8 pp. Experimental investigation which shows that the application of the magnetic field produced very little change in Reynolds Number of transition when large initial disturbances were introduced at the entrance to the flow tube. However, the magnetic field increased the Reynolds Number of transition by as much as 10% at Reynolds Numbers between 5,000 and 8,000 when only slight instabilities were present; at lower Reynolds Numbers this increase was not observed.

THE INSTABILITY OF A PINCHED FLUID WITH A LONGITUDINAL MAGNETIC FIELD. M. Kruskal. Royal Soc. (London) Proc., Ser. A, June 3, 1958, pp. 222-237. Analysis of the stability of a pinched plasma equilibrium with a longitudinal magnetic field superimposed on the characteristic azimuthal magnetic field of the pinch current. The linearized solutions are developed as helical perturbations of the plasma surface. The behavior of these is given for the different cases of a uniform longitudinal field, a longitudinal field zero inside the plasma, and for helices of the same and opposite sense to the helix which describes the total magnetic field. It is concluded that the longitudinal field has the effect of stabilizing short-wave perturbations, but that some long-wave perturbations remain unstable no matter how large the externally imposed longitudinal magnetic field.

THE INTERACTION OF A PLANE STRONG SHOCK WAVE WITH A STEADY MAGNETIC FIELD. Appendix A, B - ONE-DIMENSIONAL FLOW WITH MOMENTUM LOSS FOR AN IDEAL GAS. Appendix C - DESCRIPTION OF SOME INTERACTION EXPERIMENTS. J. H. deLeeuw. UTIA Rep. 49, Mar., 1958. 80 pp. 13 refs. Theoretical investigation of some aspects of the interaction of a magnetic field and the flow of ionized and electrically conductive argon, as it may be produced in the shock tube by strong shock waves. Three different configurations are considered. The axial components of the ponderomotive forces that act on the gas as a result of its motion through the magnetic field are calculated for each of the configurations considering the shock tubes as having nonconductive walls. The behaviour of the gas under the action of the ponderomotive forces is determined by considering the flow to be one-dimensional. Results indicate that the use of ideal gas relations is inadequate to give even an approximate indication of the real flow. Includes determination of limiting conditions beyond which shock waves can not be reflected off the magnetic field. It was found that, at a given pressure level, reflected shock waves can occur only over a limited range of Mach Numbers of the incident shock wave.

THE STRUCTURE OF A HYDROMAGNETIC SHOCK IN STEADY PLANE MOTION. G. S. S. Ludford. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-131 (AFOSR TN 58-418) [AD 158221], Apr., 1958. 26 pp. Analysis of the steady plane motion of an electrically conducting perfect viscous gas in the presence of a magnetic field in its own plane, made on the basis of classical continuum theory. The local behavior of the gas at a shock is studied by considering transitions in which all quantities, as functions of one coordinate x alone, change from finite initial values at $x = -\infty$ to finite final values at $x = +\infty$. The equations of motion are derived. It is shown that a transition flow in an electrically conducting fluid of vanishingly small viscosity contains a gas-dynamical shock only if the final state is subsonic, in which case the whole adjustment region lies upstream of the shock.

FLOW OF A VISCOUS LIQUID ON A ROTATING DISK. A. G. Emslie, F. T. Bonner, and L. G. Peck. J. Appl. Phys., May, 1958, pp. 858-862. Solution of the equations describing the flow and construction of characteristic curves and surface contours at successive times for initial fluid distribution. Several assumption for analysis simplification are made. It is shown that initially irregular fluid distributions tend toward uniformity under centrifugation. Means of computing times required to produce uniform layers of given thickness of given angular velocity and fluid viscosity are demonstrated. Edge effects on rotating planes with rising rims, and fluid flow on rotating nonplanar surfaces, are considered.

AN EXPERIMENTAL INVESTIGATION OF THE FLOW PROPERTIES BEHIND STRONG SHOCK WAVES IN NITROGEN. H. F. Waldron. UTIA Rep. 50, Mar., 1958. 52 pp. 19 refs. Measurement of pressure, particle velocity, and speed of sound in the uniform region behind shock waves up to a Mach Number of 13. From the measured

quantities, the pressure, speed of sound, density, temperature, enthalpy and flow Mach Number are calculated. The experimentally determined values confirm the considerable deviation from the ideal gas theory as predicted when vibration and dissociation are included in the calculation of the thermodynamic properties. The attenuation of a shock wave over a distance of 18 ft. from the diaphragm was investigated for a hydrogen-oxygen and a hydrogen-oxygen-helium mixture as a driver gas. Spark ignition at the closed end of the tube where a detonation wave was formed produced an attenuation of 3.2% of the incident shock Mach Number per ft. A technique approximating constant volume burning was found to attenuate the shock wave at the rate of 1.3% per ft.; when cold hydrogen was used the attenuation was 0.8%.

THE THICKNESS OF CYLINDRICAL SHOCKS AND THE PLK METHOD. H. C. Levey. Australia, ARL Rep. A.108, Jan., 1958. 27 pp. Study of the methods of solution for cylindrical shocks which occur when a viscous heat-conducting gas flows radially in a plane. This is a singular perturbation problem in which the perturbing parameter is the reciprocal of the Reynold Number R_e of the flow. It is shown that for both inward facing shocks (source flow) and outward facing shocks (sink flow) the shock thickness is of order $R_e^{-1} S^{-1} \log (R_e S^3)$ where S is the shock strength. This is contrary to the results obtained by Lighthill's PLK method, and it is shown that this method fails when applied to singular perturbation problems in which the small parameter multiplies the highest derivatives.

THE SHOCK PATTERN OF A WING-BODY COMBINATION, FAR FROM THE FLIGHT PATH. F. Walkden. Aero. Quart., May, 1958, pp. 164-194. Analysis to determine the position and strength of the front shock wave at large distances from a wing-body combination, using a method developed by Whitham. The effects of interference between the flow over the body and the flow over the wing are included. In any direction the flow far from the wing-body combination is equivalent to the flow past a body of revolution determined from the configuration of the combination. The modified formulas for unsteady flow are given and some results are evaluated for the combination of a body of revolution and a delta wing with subsonic leading edges.

DER SENKRECHTE VERDICHTUNGSSTOSS AM GEKRÜMMTEN PROFIL. J. Zierep. DVL Bericht No. 51, Apr., 1958. 36 pp. Westdeutscher Verlag, Köln & Opladen. In German. Analysis of perpendicular compression shocks occurring on a curved wall in stationary flow. The geometrical form of the shock in the wall zone is determined, and the flow in the vicinity of the wall and the shock is studied. For convex profiles, the analysis proves the existence of effects which have been observed experimentally; the importance of phenomena in localized supersonic regions and for compressible cascade flows is emphasized.

MOLECULAR APPROACH TO PROBLEMS OF HIGH-ALTITUDE, HIGH-SPEED FLIGHT. G. N. Patterson. (NATO AGARD 11th Wind-Tunnel & Model-Testing Panel, Scheveningen, July 8-12, 1957.) NATO AGARD Rep. 134, July, 1957. 58 pp. 61 refs. Analysis of the effects of rarefaction and high temperatures on the flow of gases for high-speed flight purposes. It is pointed out that flight at very high speed can only occur at extreme altitudes. The zones of the upper atmosphere, the regimes of fluid mechanics based on considerations of rarefaction and temperature, and the modern experimental methods for investigations in some of these regimes are discussed. Rarefaction effects are described in terms of gas-surface interactions, free molecule flow and slip flow, and Newtonian flow is considered as an extension of free molecule motion. The effects of high temperature are indicated for both undissociated air and air in dissociation equilibrium, and the important effects of relaxation are outlined.

AN INVESTIGATION OF THE FINE STRUCTURE OF TURBULENT FLOWS. R. Betchov. (Quart. Rev. Bumblebee Activ., Jan.-Mar., Apr.-June, 1957.) Johns Hopkins U., APL BB Rep. 270, 1958, pp. 38-42. Description of measurements made on the fine structure of turbulent flows in a tunnel designed to provide flow with a high eddy Reynolds Number and a low minimum observable motion. Some theoretical predictions, based on studies made by Kolmogoroff and Heisenberg, are made. Results of flow measurements are presented in graphical form and show that the gap between turbulence and molecular agitation is smaller than usually assumed.

Internal Flow

THE COMPRESSIBLE FLOW THROUGH CASCADE ACTUATOR DISCS. J. H. Horlock. Aero. Quart., May, 1958, pp. 110-130. 13 refs. Review of the theory of incompressible flow through two- and three-dimensional cascade actuator discs, and development of a parallel theory for subsonic compressible flow through actuator discs. Approximate solutions for several examples are considered, including a compressible shear flow through a two-dimensional cascade, and a compressible flow through an annular cascade of guide vanes.

SECONDARY FLOWS IN AN AXIAL COMPRESSOR. J. Valensi. Inst. Méc. Fluides, Lille, Final Rep. (EOARDC TR 58-40) [AD 154123], Nov. 8, 1957. 61 pp. 19 refs. Depiction of the mean flow and investigation of secondary flow effects near the walls and through the blade passages by means of smoke visualization. A theoretical and experimental analysis of vorticity distribution is made. Analyses of the rotating stall flow pattern on a single stage axial compressor are made by means of dynamic stagnation, static pressure measurements, and smoke surveys. The results of both techniques are in good agreement. Smoke surveys appear to be of great assistance in the explanation of the rotating stall mechanism. They give a clear evidence of the three-dimensional pattern of the phenomenon which might be a determinant factor for the different characteristics of rotating stall.

INVESTIGATION OF THE EFFECTIVENESS OF A WINDMILL FOR IMPROVING FLOW UNIFORMITY IN A DUCT. J. S. Murphy and D. W. Clutter. Douglas Rep. ES-26393, Oct. 8, 1957. 102 pp. Description of tests to determine the effectiveness of a freely rotating windmill in smoothing out nonuniform duct flow. The design of the windmill and the forces acting on it due to changes in wind speed are discussed. Experimental results show the effect of blade angle and number of blades on the windmill's effectiveness in smoothing out a wide variety of disturbance profiles, both circumferential and radial. The 10-bladed windmill tested was about 50% effective in reducing the disturbances introduced by the distortion devices regardless of the type or amplitude of the disturbances. A 29% - solidity screen was investigated for comparison purposes. When compared on the basis of effectiveness per unit drag, the windmill devices were about six times better than the screen in smoothing out nonuniform duct flow, its main disadvantages being complexity and increased weight.

INCOMPRESSIBLE FRICTION FACTOR, TRANSITION AND HYDRODYNAMIC ENTRANCE LENGTH STUDIES OF DUCTS WITH TRIANGULAR AND RECTANGULAR CROSS-SECTIONS. E. R. G. Eckert and T. F. Irvine, Jr. USAF WADC TR 58-95 [AD 151027], Apr., 1957. 29 refs. Investigation of air flowing with subsonic velocities through noncircular ducts, presenting measurements on friction factors, critical Reynolds Number, and hydrodynamic entrance lengths. Data are obtained on a 23° isosceles triangle and a rectangle having a breadth to depth ratio of three. Results show that contrary to measurements by Nikuradse, the friction factors for developed flow in the laminar range followed analytical predictions. In the turbulent range, the Blasius relation based on the hydraulic diameter describes the experimental results satisfactorily. Transition is found to depend on entrance conditions. The measurements indicate that the use of a momentum correction term to evaluate entrance pressure losses for the two duct shapes investigated is accurate to within 15%.

A PERFORMANCE ANALYSIS OF METHODS FOR HANDLING EXCESS INLET FLOW AT SUPERSONIC SPEEDS. D. P. Hearth and J. F. Connors. US, NACA TN 4270, May, 1958. 26 pp. Comparison of techniques which are examined and evaluated in terms of their respective thrust penalties for an assumed turbojet engine over a Mach Number range from 1.5 to 4.0. These are: normal- and oblique-shock spillage, bypassing through an auxiliary exit, bypassing to an ejector exhaust nozzle, and bypassing the excess flow through an auxiliary ramjet engine. Charts are presented for estimating these penalties for a range of mass flows and Mach Numbers.

THE FLOW OF A SUPERSONIC JET IN A SUPERSONIC STREAM AT AN ANGLE OF ATTACK. F. E. Ehlers and Torstein Strand. J. Aero/Space Sci., Aug., 1958, pp. 497-506. Solution of the linearized equations for the flow of a supersonic jet at a small angle of attack in a supersonic stream using the Laplace-transform theory. The role of the parameter k in the reflections from the boundary is stated. If $k = 1$, for two dimensions there are no reflections from the jet interface, and the jet aligns itself with the original undisturbed flow in a finite distance. For $k > 1$ and zero angle of attack, the jet interface for the symmetrical solution oscillates between positive and negative slope, but for $k < 1$ the slope decreases monotonically. The angle of attack term, however, indicates a waving boundary only for $k < 1$. The three-dimensional solution has no oscillations of the boundary if $k = 1$. Simple relations are obtained for the perturbation velocity potentials near the Mach cone from the rim, and far downstream of the jet exhaust. The pressure discontinuity decay takes the form of $1/\sqrt{r}$ along the Mach line from the rim of the jet. The influence of the tube length before the cylindrical jet exhaust on the deflection of the jet due to the angle of attack is described.

Jet Flaps & Wings

AN INVESTIGATION OF THE EFFECTS OF THICKNESS, CAMBER AND NOSE RADIUS ON THE PERFORMANCE OF JET-FLAPPED AEROFOILS. J. A. Beasley. Gt. Brit., RAE TN Aero. 2534, Oct., 1957. 18 pp. 11 refs. Calculation of pressure distributions by Küchemann's method for six airfoils with jets blowing over 15% flaps, deflected 60°. A qualitative assessment of the efficacy of several airfoil parameters in preventing flow separation near the leading edge is made. The effects of varying jet deflection angle and incidence are also discussed. A comparison between the pressure distributions of two airfoils of 12% and 24% thickness-chord ratios shows that considerable thickness is essential for the attainment of very high lift coefficients. Camber and a large nose radius are shown to be beneficial but cannot by themselves make a thin airfoil practicable for high lift coefficients, and should be regarded only as a means of improving the performance of a very thick airfoil. A negative effective incidence may be advantageous, since this produces a reduction in the leading edge suction peak.

THE THEORETICAL EVALUATION OF THE DOWNWASH BEHIND JET-FLAPPED WINGS. A. J. Ross. Gt. Brit., RAE Rep. Aero. 2599, Jan., 1958. 45 pp. Evaluation of the downwash behind jet-flapped wings of infinite and finite span, using the solutions given by Spence and Maskell for the flow in two and three dimensions, respectively. The wing incidence and jet deflection are assumed to be small, and the spanwise loading on the finite wing elliptic. The wake is considered to be a flat sheet. Charts are given for the functions required in the calculation of the downwash for four specific values of jet momentum coefficient. Theoretical results for the downwash on the center line are given for a wing of aspect ratio 6.0, showing variation with tailplane position, wing incidence, and jet parameters. Calculated values of the downwash are in good agreement with the available experimental results.

Stability & Control

DIE STRUKTURELLE STABILITÄT LINEARER EINLÄUFIGER PID-REGELKREISE MIT DIFFERENZIERENDER WIRKUNG VON HÖCHSTENS ZWEITER ORDNUNG. S. Lehnigk. DFL Inst. Flugmech. Bericht 81, May 12, 1957. 78 pp. 17 refs. In German. Study of the structural stability of a linear continuous PID control loop with maximum second-order differentiating effects. Includes definitions and mathematical descriptions of the PID loop (Proportional-Integrating-Differentiating loop) and formulation of the stability problem. Necessary conditions for the existence of a stability region are derived for a structure characterized by a given polynomial. Examples of applications are also presented. These include (a) aircraft longitudinal control and (b) stability of sailplanes under given flight conditions with change in flying velocity and dependence of longitudinal motion.

Wings & Airfoils

THE CALCULATION OF LIFT SLOPES, ALLOWING FOR BOUNDARY LAYER, WITH APPLICATIONS TO THE RAE 101 AND 104 AEROFOILS. Appendix - CIRCULATION IN THE WAKE. D. A. Spence and J. A. Beasley. Gt. Brit., RAE Rep. Aero. 2598, Feb., 1958. 29 pp. 15 refs. Presentation of a simplified method to calculate the loss of lift below the ideal flow value caused by the boundary layer. The percentage of the ideal lift developed is calculated for the RAE 101 and 104 airfoils with thickness/chord ratios of 6, 10, and 15% in each case, at Reynolds Numbers of 10^6, 10^7, and 10^8. The majority of the calculations are made with $\alpha = 2^\circ$, and a few cases with $\alpha = 4^\circ$ and 6° are included for comparison. The location of transition is treated as an external parameter. Good agreement exists between prediction and measurement for the 10% thick 101 section tested by Brebner and Bagley.

EXPERIMENTS ON THE EFFECTS OF AIR JETS AND SURFACE ROUGHNESS ON THE STALLING CHARACTERISTICS OF A 5 FT. CHORD NACA 64A006 AEROFOIL. D. G. Hurley, R. A. Wallis, and Mary Calame. Australia, ARL Rep. A.107, Dec., 1957. 48 pp. 11 refs. Investigation showing that spanwise rows of air jets or suitably controlled roughness located near the leading edge lead to appreciable increases in the nose stalling incidence of the airfoil with resulting improvements in its lift, drag, and pitching moment characteristics. Air jets or roughness used on the lower surface reduced the laminar separation bubble to minute proportions and air jets on the upper surface led to a small delay in turbulent separation.

ON THE LIFT AND INDUCED DRAG ASSOCIATED WITH LARGE DOWNWASH ANGLES. H. S. Ribner. UTIA TN 19, Jan., 1958. 20 pp. Evaluation by means of a momentum balance of the lift and induced drag for an arbitrary wing-wake vortex pattern with a large downwash. The entire induction effect of the wake is found to be representable as a "generalized" induced drag vector parallel to the asymptotic trailing vortex direction. The vertical component of this drag constitutes a nonlinear contribution to lift. A possible similar behavior of the parasite drag is indicated. The Jones low-aspect-ratio wing theory has been reformulated to apply to large angles of attack; it gives complete agreement with the momentum balance results.

GENERAL SOLUTIONS FOR FLOW PAST SLENDER CAMBERED WINGS WITH SWEPT TRAILING EDGES AND CALCULATION OF ADDITIONAL LOADING DUE TO CONTROL SURFACES. E. B. Klunker and K. C. Harder. US, NACA TN 4242, May, 1958. 55 pp. 12 refs. Analysis to obtain general expressions for the surface pressure, lift, and rolling moment of cambered wings with swept trailing edges. These results are specialized to give the additional loading due to the deflection of trailing-edge control surfaces and the loading due to a particular type of wing twist. In contrast to flat-plate wings, cambered surfaces (or wings with control surfaces) support a load downstream of the maximum span of the wing where the slope of the leading edge is equal to or less than zero. The pressure distribution and the streamwise lift and rolling-moment distribution are discontinuous across the plane normal to the stream direction passing through the wing maximum span unless the slope of the wing leading edge is continuous and zero at this chordwise station.

AEROELASTICITY

AEROELASTISCHES KOLLOQUIUM. I - RECHENVERFAHREN ZUR LÖSUNG AEROELASTISCHER AUFGABEN FÜR PLATTENARTIGE FLÜGEL UND FÜR DAS GANZE FLUGZEUG. H. G. Küssner. II - FLATTERRECHNUNGEN FÜR MODERNE FLUGZEUGE MIT VIELEN FREIHEITSGRADEN. A. I. van de Vooren. III - DIE SINNVOLLE EINFÜHRUNG DER IM STANDSCHWINGUNGSVERSUCH GEMESSENEN GRÖSSEN IN DIE FLATTERRECHNUNG. G. de Vries. IV - EINIGE FLATTERRECHNUNGEN FÜR QUERRUDER MIT HYDRAULISCHER SERVOSTEUERUNG. E. Gruschwitz. V - EXPERIMENTELLE BESTIMMUNG DER AERODYNAMISCHEN BEIWERTE SCHWINGENDER FLÜGEL. H. Bergh. VI - BESTIMMUNG INSTATIONÄRER LUFTKRÄFTE BEI M = 0 MIT HILFE ELEKTRISCHER ANALOGIE (POTENTIALTANK). H. Merbt and S. Hansson. VII - STANDSCHWINGUNGSVERSUCH AN EINEM SEGELFLUGZEUG MIT ELEKTRONISCHEN MESSGERÄTEN. J. Schoen. (Aerolastisches Kolloquium, Göttingen, Apr. 16, 17, 1957.) Max-Planck-Inst. Strömungsforschung & Aero. Versuchsanst., Mitteil. No. 18, 1958. 180 pp. 28 refs. DM 17. In German. I - Presentation of calculation techniques for solving the problems of aeroelasticity applied to the case of a thin, short wing and that of the entire aircraft. The wing is considered as a flat plate with distributed point loads representing the continuous loading. Includes derivation of the integral-equation method and of the Rayleigh-Ritz and Galerkin equations, as well as presentation of numerical examples. II - Calculation of flutter characteristics for a large transport aircraft, der-

ivation of a simplified method, as well as discussion of the use of ground vibration tests, with a comparison of theoretical and measured values. III - Discussion covering the introduction of measured values obtained from static vibration tests into the flutter calculation, including derivation of a simplified method. IV - Presentation of flutter calculations for an aileron with hydraulic servocontrol. V - Experimental determination of aerodynamic coefficients for an oscillating wing. VI - Calculation of nonstationary air forces for M = 0 by means of an electric analog; derivation of the basic theory and method for the two-dimensional case; and description of the measuring techniques, as well as results for the case of a rectangular wing. VII - Description of an installation for static vibration experiments and application to glider tests.

INVESTIGATION OF A METHOD FOR THE MEASUREMENT OF SUBSONIC OSCILLATORY AERODYNAMIC INFLUENCE COEFFICIENTS. H. N. Abramson and P. A. Beckmann, Jr. USAF WADC TR 57-736 [AD 142201], Dec., 1957. 68 pp. 14 refs. Presentation of results from wind tunnel tests conducted on a rigid two-dimensional wing model to determine the oscillatory pressures at various points on the planform resulting from a pulsating downwash source at a fixed point on the planform. The pulsating downwash is produced by a specially designed apparatus and pressures are recorded by means of differential pressure transducers and electronic recording equipment. Test results are compared with theoretical predictions, in so far as these are available. It is concluded that the experimental method developed during this program is a feasible one for the measurement of oscillatory aerodynamic influence coefficients.

K VOPROSU O VYNUZHDENNYKH PSEVDOGARMONICHESKIKH KOLEBANII STERZHNEI S UPRUGO-PLASTICHESKIMI OPORAMI. V. A. Ivovich. AN SSSR Dokl., Mar. 1, 1958, pp. 42-45. In Russian. Investigation of the problem of forced pseudoharmonic oscillations of rods resting on resilient supports. Includes derivation of the equation of motion and description of the method in which the external harmonic force is replaced by a force obeying a time-variation law similar to the pattern of natural oscillations. A characteristic of the problem is that the variation pattern of the selected function approximating the exciting force is similar to the trigonometric for small values of nonlinear terms. The approximate solution, obtained by this method for the harmonic case, appears to be sufficiently accurate for practical application in the field of free oscillations for all values of the amplitude, as well as in the case of small amplitude.

CALCUL ET ESSAIS DE FLOTTEMENT EN SOUFFLERIE ET EN AIR LIBRE SUR AILES SEMBLABLES. H. Loiseau. La Recherche Aéronautique, Mar.-Apr., 1958, pp. 13-18. In French. Description of flutter calculations and wind-tunnel and free-atmosphere tests on geometrically and structurally similar wings with two degrees of freedom. Results of theoretical calculations, wind tunnel tests on single wings, and flight tests on winged models are discussed and compared. The need for model flight tests to supplement wind tunnel experiments is emphasized, and an evaluation of the magnitude of errors is made.

ETUDE DU FLOTTEMENT EN REGIME TRANSSONIQUE. G. Coupry and G. Piazzoli. La Recherche Aéronautique, Mar.-Apr., 1958, pp. 19-28. In French. Description of experiments carried out at ONERA and covering the effect of shock thickness and motion on aerodynamic coefficients of a thick symmetrical profile at zero incidence. Includes development of a method applied (a) for an upstream Mach Number at infinity slightly greater than unity, (b) to calculate the shock recoil for a profile at steady incidence, and (c) to calculate out-of-phase magnitude for shock movement in relation to flap moment for various reduced frequencies.

BENDING AND VIBRATION OF ELASTICALLY RESTRAINED CIRCULAR PLATES. C. L. Kantham. Franklin Inst. J., June, 1958, pp. 483-491. 10 refs. Analysis of a general boundary condition involving a linear relation between moment and slope at an edge, so that the simply supported and completely fixed edge conditions form the limiting cases. The constant of proportionality is the elastic restraint factor, which is a measure of the degree of fixture, varying from zero to positive infinity. Values of deflection and natural frequency are determined for intermediate values of the elastic restraint factor. Curves are given to determine the elastic restraint for a circular plate by measuring the deflection at the center in one case, and the frequencies in the other case. It is shown that in bending and vibration problems the values for the two limiting cases of simply supported edge and clamped edge are reached asymptotically.

AIRPLANES

Design

IMPORTANCE OF SHAPE OF STRINGER SECTION IN PRESSURE-CABIN DESIGN. D. Williams. Gt. Brit., RAE TN Struc. 234, Mar., 1958. 8 pp. Study showing that the effectiveness of the stringers in restricting the radial expansion of the cabin skin between frames depends upon the shape of the stringer cross-section. Some stringer sections are not suitable for providing the necessary support because a sideways twisting action prevents the stiffness from being exerted. It is shown for an angle section that, under the inward radial pull of the frame or band, the bending stiffness of the stringer never comes into action. Other stringer sections that are equally unfavorable are the channel and the straight ⅃ section. The top-hat type of section does not suffer from any of the above disabilities and is admirably suited to the task of holding down the skin between bands.

AVIATION MEDICINE, SPACE MEDICINE

ZUR PRAXIS DER FLIEGERTAUGLICHKEITSUNTERSUCHUNG. I - MITTEILUNG: DER SAUER-

STOFFMANGEL ALS BELASTUNGSUNTERSUCHUNG ZUR ERMITTLUNG DES SUMMENWERTES DER LEISTUNGSRESERVE. H. Brüner and K. Dietmann. DVL Bericht No. 60, Apr., 1958. 21 pp. 21 refs. Westdeutscher Verlag, Köln & Opladen. In German. Discussion of methods for investigating the fitness of airmen, covering (a) the use of oxygen deprivation as stress-inducing means in evaluating total reserves of mental and manipulative ability and (b) application of the "ball-test" apparatus to assess the ability of a subject in a chamber simulating given altitudes. Includes derivation and analysis of typical performance curves.

ELECTRONICS

Semiconductors

VALENTNYE POLUPROVODNIKI - GERMANII I KREMNII. G. I. Fen. Uspekhi Fiz. Nauk, Apr., 1958, pp. 733-779. In Russian. Survey of data on the characteristics of germanium and silicon crystals. Includes: evaluation of the semiconductor theory, ideal crystals, perturbation of the crystal lattice, electron distribution, effective mass; properties of crystals, crystal lattice, optical properties and dielectric constant, magnetic properties, effective mass and structure of the energy zone, impurities, crystal lattice flaws; conductivity phenomena, general theory, conductivity and Hall effect, thermoelectromotive force, conductivity in the case of strong fields, low temperature, and high frequency; and problems related to the biased electron distribution.

FUELS & LUBRICANTS

THEORETICAL ROCKET PERFORMANCE OF LIQUID METHANE WITH SEVERAL FLUORINE-OXYGEN MIXTURES ASSUMING FROZEN COMPOSITION. Sanford Gordon and M. E. Kastner. US, NACA RM E58B20, May 20, 1958. 44 pp. 15 refs. Calculation of theoretical rocket performance for frozen composition during expansion of liquid methane with several fluorine-oxygen mixtures over a range of pressure ratios and oxidant-fuel ratios. Parameters included are specific impulse, combustion and exit temperatures, molecular weight, characteristic velocity, coefficient of thrust, area ratio, specific heat, isentropic exponent, viscosity, thermal conductivity, and combustion compositions. The calculated values of the various performance parameters for a combustion pressure of 600 psia and for a range of oxidant-fuel ratios and exit conditions are tabulated for a range of fluorine-oxygen ratios. The maximum value of specific impulse calculated for a chamber pressure of 600 psia and an exit pressure of 1 atmosphere is 315.3 for 79.67% fluorine in the oxidant.

THEORETICAL PERFORMANCE OF LIQUID AMMONIA WITH LIQUID OXYGEN AS A ROCKET PROPELLANT. Sanford Gordon and A. R. Glueck. US, NACA RM E58A21, May 12, 1958. 84 pp. 29 refs. Calculations of both equilibrium and frozen composition during expansion for two chamber pressures (300 and 600 psia), and a wide range of pressure ratios (1 to 1, 500) and oxidant-fuel ratios (0.564 to 7.046). The parameters included are specific impulse, specific impulse in vacuum, combustion-chamber temperature, nozzle-exit temperature, molecular weight, molecular-weight derivatives, characteristic velocity, coefficient of thrust, ratio of nozzle-exit area to throat area, specific heat at constant pressure, isentropic exponent, viscosity, thermal conductivity, Mach Number, and equilibrium gas compositions. The maximum value of specific impulse for a chamber pressure of 600 psia and an exit pressure of one atmosphere is 278.7 and 269.3 assuming equilibrium and frozen composition, respectively.

MISSILES

GENERAL VARIATIONAL THEORY OF THE FLIGHT PATHS OF ROCKET-POWERED AIRCRAFT, MISSILES AND SATELLITE CARRIERS. Appendix A - REMARKS ON THE VERTICAL FLIGHT OF A ROCKET TRAVELLING IN AN ISOTHERMAL MEDIUM. Appendix B - THE FLIGHT PATHS OF INTERCEPTOR MISSILES. Angelo Miele Purdue U. Sch. Aero. Eng. Rep. A-58-2 (AFOSR TN 58-246) [AD 154148], Jan., 1958. 63 pp. 16 refs. Presentation of a basic theory for analyzing the optimum flight paths of rocket-powered aircraft, missiles, and satellites. The problem with three degrees of freedom is considered; it consists of the simultaneous optimization of the time history of lift, thrust modulus, and thrust direction. Special problems involving either one or two degrees of freedom are investigated by the introduction of additional constraining equations. For some of these problems closed form expressions are derived for the optimizing conditions. Furthermore, a complete formulation of the boundary conditions is supplied by means of the general transversality condition of the calculus of variations.

THE EMPLOYMENT OF AERODYNAMIC FORCES TO OBTAIN MAXIMUM RANGE OF A ROCKET MISSILE. D. F. Lawden. Aero. Quart., May, 1958, pp. 97-109. Analysis considering the programing of the thrust direction for a missile in order to obtain maximum range over a flat earth by the most favorable use of the aerodynamic forces for the special case when these forces are small in comparison with the missile weight. The cases of a V-2-type missile with and without lift are dealt with in detail, and numerical results are computed.

OPTIMUM THRUST PROGRAMMING ALONG ARBITRARILY INCLINED RECTILINEAR PATHS. Angelo Miele and C. R. Cavoti. Purdue U. Sch. Aero. Eng. Rep. A-57-8 (AFOSR TN 58-48) [AD 148088], Dec., 1957. 25 pp. Analysis of a rocket-powered vehicle moving along an arbitrarily inclined rectilinear path, and determination of the burning program which minimizes an arbitrarily specified function of the initial and final values for mass, velocity, and altitude. It is shown that the totality of extremal arcs includes zero-thrust sub-arcs, sub-arcs to be flown with maximum engine output, and variable-thrust sub-arcs. General solutions

are derived for the optimizing condition, embodying as a particular case previously developed work. The analysis is confined to problems not involving time, but can be extended to cover the case where time condition is imposed on the flight trajectory. The optimum acceleration law is determined, and some numerical examples are presented which emphasize the engineering aspects of the present theory in connection with the flight analysis of rockets.

ANGLE OF ATTACK CONVERGENCE OF A SPINNING MISSILE DESCENDING THROUGH THE ATMOSPHERE. H. I. Leon. J. Aero/Space Sci., Aug., 1958, pp. 480-484. Derivation of the angular motion of a spinning missile descending through an exponential atmosphere for the case of small angles of attack. It is found that the angle of attack envelope is increased during re-entry for a spinning missile over that for a nonspinning one. For an initial attitude error and no wobble or tumble rate, the angle of attack envelope is increased over nonspinning re-entry by an amount dependent on the spin rate, altitude, plus trajectory and missile parameters. The effect of initial tumble rates at spin-up generates a wobble, which gives rise to a nutation during re-entry.

VERTICAL DESCENT TRAJECTORIES INCLUDING RE-ENTRY INTO THE ATMOSPHERE. Appendix - COMPUTER PROCEDURES. Reinhard Krause and W. F. Haldeman. USAF MDC TR 58-4 [AD 135011], Mar., 1958. 81 pp. Calculation of trajectories for bodies descending vertically through the atmosphere, for a wide range of initial altitudes and body characteristics to provide information required for design purposes. Parameters and equations, as well as the method of calculation by means of an analog computer, are discussed. The results are plotted as velocity vs. altitude and time vs. altitude.

TRAJECTORY DETERMINATION OF A SUPERSONIC BODY BY ACOUSTICAL OBSERVATIONS. G. V. Groves. J. Atmos. & Terrestrial Phys., No. 1, 1958, pp. 17-25. Development of a theory for deriving the trajectory of a body moving at supersonic speeds through the atmosphere, from observations on the times of arrival of its shock wave at a number of microphones at known points on the ground, wind and temperature effects being taken into account. It is shown that with 3n + 4 microphones, the position, velocity, and acceleration up to the nth derivative of the spatial coordinates of the body with respect to time can be found at some determined instant of time. Hence, with seven microphones, the position and velocity of the body at a certain instant of time can be found.

NAVIGATION

ELEKTRISCHE MESSVERFAHREN IN DER GEODÄSIE. J. Lorentz and K. Brocks. DVL Bericht No. 54, Apr., 1958. 107 pp. 262 refs. Westdeutscher Verlag, Köln & Opladen. In German. Survey of classical applications of electrical measuring systems to geodesy, description of the operation of these systems, as well as review of various methods and evaluation of their accuracy. Electrical techniques include those combined with optical systems where electrical instruments are used for timing, recording, or signaling the arrival of light impulses. The potentialities and limitations of radar systems for distance measurement are discussed with reference to Decca and Shoran systems.

NUCLEAR ENERGY

DIRECT CYCLE NUCLEAR TURBOJET POWER PLANTS. E. L. Semple and W. C. Cooley. Aero/Space Engrg., Aug., 1958, pp. 30-35. Analysis to estimate the effects of some of the important design parameters on the flight performance and to outline some of the characteristics of the direct cycle nuclear power plant. The power-plant weight is investigated in order to estimate the thrust/weight ratio attainable with the nuclear turbojet. The relationship between engine thermodynamic cycle and the core diameter of the reactor is determined by considering the heat-transfer characteristics of the reactor core. Series of graphs show the effect of each of the independent variables required on the power-plant thrust/weight ratio. Two of the most significant factors affecting the aircraft capabilities are the turbine inlet temperature and the reactor free flow fraction; both should be as high as possible to obtain the maximum thrust/weight ratio.

BESONDERE BRENNSTOFFVERTEILUNGEN UND KÜHLUNGSPROBLEME IN REAKTOREN VON KERNRAKETEN. F. Winterberg. Astronautica Acta, Fasc. 2, 1958, pp. 138-165. In German. Discussion of special fuel distribution and cooling problems in rocket nuclear reactors. It is shown that favorable fuel distributions are those that result in a constant density of expended energy in the core of the reactor, and others, where the surface temperature of the cooling channels remains constant. Includes some numerical examples.

PHYSICS

DIFFUSION AND ELASTIC COLLISION LOSSES OF THE "FAST ELECTRONS" IN PLASMAS. G. Medicus. J. Appl. Phys., June, 1958, pp. 903-908. Evaluation of experimental data for the mean free path ℓ of the fast electrons by means of the diffusion law. It is found that ℓ is independent of the plasma density and is about equal to the value calculated from the cross-section function for 10-16 volt electrons in Ne. The diffusion law also allows the calculation of the elastic collision losses of the fast group; they are found to be relatively small compared to the total energy losses of the fast electrons. An example of the overall validity of the diffusion law is shown in graphical form. The most remarkable result is the low interaction of the fast group with the Maxwellian group at low total plasma densities where the partial density of the slow group is always comparable to or even much higher than the fast group.

ISSLEDOVANIE PLAZMY PRI POMOSHCHI MIKRORADIOVOLN. M. D. Raizen and I. S.

Shpigel'. Uspekhi Fiz. Nauk, Apr., 1958, pp. 641-667. 55 refs. In Russian. Evaluation of microradiowave methods for plasma investigations showing possible approaches to the study of various phenomena occurring in plasma and presentation of data on the behavior of charged particles. The analysis covers conductivity and dielectric constant of ionized gases; resonator, wave-guide, and cross-modulation methods; determination of ambipolar diffusion coefficients, recombination, and frequencies of electron collision; and experimental results.

V - STATISTICAL MECHANICS OF MATTER IN AN ELECTROMAGNETIC FIELD MOMENTUM BALANCE OF SYSTEMS WITH MAGNETIZATION AND POLARIZATION. S. R. Grott. Leiden U. Rep. (AFOSR TN 58-232) [AD 154135], Jan., 1958. 19 pp. Classical statistical derivation of the macroscopic momentum balance equation for an uncharged fluid with magnetization and polarization in an external electromagnetic field. The classical equations of motion of the spinless electrons and nuclei are derived from a Lagrangian, first given by Darwin. The classical statistical formalism is used to derive the momentum balance of the system. Expressions for pressure and ponderomotive force of the fluid are defined in terms of averages over miscroscopic quantities.

STABILITY STUDIES WITH LONGITUDINAL MAGNETIC FIELD ON A STRAIGHT PINCHED DISCHARGE. L. C. Burkhardt, R. H. Lovberg, G. A. Sawyer, and T. F. Stratton. J. Appl. Phys., June, 1958, pp. 964-967. Determination of the effect of a longitudinal magnetic field on instabilities in a linear pinched discharge. The two classes of particular interest are those for which $m = 0$, and $m = 1$. Experiments indicate that the characteristic $m = 0$ short wave length instabilities are suppressed by B_z fields, and that pinch life is lengthened. Measurements with a system of magnetic probes indicate that the remaining instability is a long wave length $m = 1$ helix. Image converter photographs of the pinch development and the short wave length instabilities are presented.

POWER PLANTS

PRELIMINARY DESIGN STUDY OF THE PRC WAVE ENGINE. Propulsion Res. Corp. Rep. R-284 (AFOSR TR 58-55) [AD 154207], Feb., 1958. 30 pp. Preliminary design studies of the PRC wave engine, as well as selection of a configuration for a model engine to conduct feasibility tests and to determine mechanical problems and real fluid effects associated with this type of engine. Initial layouts for the engine and test rig are presented. Mechanical and aerothermodynamic problems are considered. Stress studies were made of the model engine designed for 1,000 hours life at a maximum cycle temperature of 3,000 R. and rotational speeds up to 33,000 r.p.m. The most severe conditions occurred at 7,650 r.p.m. and the maximum rotational speed of 33,000 r.p.m. The overall weights of the model engine are calculated, and the layout of a fuel metering system is shown in graphical form.

APPLICATION OF THE CLOSED CYCLE PRINCIPLE TO AIRCRAFT AUXILIARY POWER PLANTS. XI - INVESTIGATION OF THE INFLUENCE OF THE FLOW FACTOR ON TURBINE EFFICIENCY. R. Tognoni and W. Spillmann. Escher-Wyss TN 7, vol. XI, Rep. Sp-AK-57-043 (EOARDC TR 58-35) [AD 152244], July 21, 1957. 9 pp. Discussion of a means for stage reductions in the compressor of a helium system, assuming equal tip speeds, by increasing the flow factors of the turbine.

PRELIMINARY SURVEY OF PROPULSION USING CHEMICAL ENERGY STORED IN THE UPPER ATMOSPHERE. Appendix A, B - COMPARISON OF TABULATED PHYSICAL PROPERTIES AND CHEMICAL-ENERGY SOURCES OF UPPER ATMOSPHERE. Appendix C - COMPARISON OF ENERGY AVAILABLE WITH ENERGY REQUIRED FOR FLIGHT. Appendix D - HEAT TRANSFER AND FRICTION DRAG. J. F. Schmidt. Appendix E - NORMAL-SHOCK ORBITING RAMJET CYCLE. Appendix F - CHEMICAL KINETICS OF RECOMBINATION. L. V. Baldwin and P. L. Blackshear. US, NACA TN 4267, May, 1958. 73 pp. 24 refs. Study of a ramjet using the chemical energy of dissociated molecules in the ionosphere for propulsion. The physical properties and the chemical composition of the upper atmosphere are reviewed; the external drag, recombination kinetics, and aerodynamic heating problems of an orbiting ramjet are analyzed. A comparison of maximum thrust and external drag for an orbiting ramjet from 300,000 to 700,000 ft. shows that a possible net-thrust margin might be obtained over the entire region for some of the engine sizes considered. The region between 325,000 and 400,000 ft. is the most favorable, because high gas densities produce high recombination rates. Approximate calculations of the rate of recombination indicate that up to 50% recombination is possible for a 100-ft. -long nozzle which would give thrust in excess of the drag.

PROPULSIVE PROPERTIES OF HIGH INTENSITY PLASMA JETS. Appendix A - GENERAL ROCKET EQUATIONS. Appendix B - THERMODYNAMIC ANALYSIS. Appendix C - GAS DYNAMIC FLOW ANALYSIS OF PLASMA JET. Appendix D - MAGNETIC FORCES ON AN ARC. A. C. Ducati and G. L. Cann. Giannini Res. Lab. TR 9 (AFOSR TN 57-748) [AD 136736], Feb. 21, 1958. 138 pp. Development of a continuously operating plasma generator and experimental investigation of high intensity ionic propulsive jets. A preliminary investigation of the propulsive properties indicated that the specific impulses of 200 and 500 could easily be obtained for argon and helium, respectively, as a result of the direct transfer of electrical energy to the gas. Electrode and nozzle configuration are found to have a definite effect on the ratio of internal energy in the gas to ionization energy at the front exit area. Practically all of the energy in the form of nonequilibrium ionization can be assumed to be transferred to the random particle motion and direct kinetic energy of the gas. The radiated energy is included to some extent in the energy absorbed by the cooling system.

XUM

A PRELIMINARY INVESTIGATION OF AN ATOMIC-OXYGEN POWER PLANT. Appendix A - INTENSIVE PROPERTIES OF UPPER ATMOSPHERE. Appendix B - EQUILIBRIUM COMPOSITIONS OF AIR AS A FUNCTION OF TEMPERATURE, PRESSURE, AND COMPOSITION OF UPPER ATMOSPHERE. Appendix C - RECOMBINATION RATES OF ATOMIC OXYGEN. S. T. Demetriades and C. B. Kretschmer. Aerojet-Gen. TN 23 (AFOSR TN 58-325) [AD 154229], Mar. 4, 1958. 50 pp. 28 refs. Theoretical design of an atomic-oxygen power plant of the ramjet type and attempt to maximize its thrust. Estimates of the aerodynamic drag are presented, and the calculations at orbital velocity (8×10^5 cm./sec.) are given special emphasis. It is shown that flight at orbital speeds can only be sustained if the radius of the power plant is greater than its length. A purely catalytic, atomic-oxygen power plant would require an effective length several times greater than the inlet radius and therefore cannot fly at orbital speeds. Flight at low speeds ($M < 10$) is not easily practicable because the structure of the vehicle has to weigh in the order of 0.01 gm./cm.^{2} of lift-producing surface. However, flight of an atomic-oxygen ramjet at orbital speeds becomes feasible if the drag can be reduced by a factor of 10 or more and if the total recombination rate can be increased by a factor of 10 or more.

Jet & Turbine

CALCULATION OF FLUID FLOW IN A VARIABLE-AREA CAN COMBUSTOR. F. Falk, J. J. Zelinski, and E. C. Bagnall. (Quart. Rev. Bumblebee Activ., Jan.-Mar., Apr.-June, 1957.) Johns Hopkins U., APL BB Rep. 270, 1958, pp. 14-18. Development of a method for calculating the effect of flameholder geometry upon the flow parameters for fluid flow without heat release. The calculation was performed for flow through a two-dimensional can combustor with matching hole patterns in two plates. Three cases were considered: (a) jets dissipating immediately upon passing through the holes, (b) jets flowing at constant entry angle and dissipating after one stage, and (c) jets bending under the influence of the main stream and dissipating only if they penetrate to the centerline of the configuration. The experimental measurements used to verify the methods of calculation include mass flow rate, static pressure at station zero, total temperature at station zero, static pressure distribution downstream of the can-type combustor, and hardware geometry.

FACTORS GOVERNING THE IGNITION DELAY OF GASEOUS FUELS. Appendix - THE APPLICATION OF SECOND ORDER REACTION RATE THEORY TO THE PROBLEM OF SPONTANEOUS IGNITION. R. E. Miller. Gt. Brit., NGTE Rep. R. 216, Mar., 1958. 39 pp. 12 refs. Investigation of the variation in ignition delay with temperatures, taking into account variations in the concentration of fuel, oxygen, and steam. The results indicate that ignition delay is inversely proportional to the oxygen index, independent of fuel concentration for the weak mixture considered here, decreases exponentially with temperature, and that the addition of steam causes an increase in ignition delay.

Rocket

EXHAUST NOZZLE CONTOUR FOR OPTIMUM THRUST. G. V. R. Rao. (ARS Semi-Annual Meeting, San Francisco, June 10-13, 1957.) Jet Propulsion, June, 1958, pp. 377-382. Development of a method for designing the wall contour of an optimum thrust nozzle by applying the calculus of variations. The nozzle length, ambient pressure, and flow conditions in the immediate vicinity of the throat appear as governing conditions under which the thrust on the nozzle is maximized. Isentropic flow is assumed, and the variational integral of this maximizing problem is formulated by considering a suitably chosen control surface. Typical nozzle configurations are presented in graphical form. The solution of the variational problem yields certain flow properties on the control surface, and the nozzle contour is constructed by the method of characteristics to give this flow. A comparison of thrust coefficients indicates that the advantage of contoured nozzles is greater at larger area ratios.

PROPELLERS

AERODYNAMIC TIP THEORY OF A SUPERSONIC PROPELLER. R. W. Hale. Cornell U., Grad. Sch. Aero. Eng. Rep. (AFOSR TN 58-355), Feb., 1958. 67 pp. 18 refs. Analysis of the tip effects of a supersonic propeller by using the approximate potential for a "helical" source developed by Ordway in an extension of the tip theory of Evvard and Krasilshchikova for wings in ordinary rectilinear supersonic flow. The blades are assumed to be lightly-loaded and attached to an infinite cylinder as a hub, whose diameter is large enough to make the relative flow velocity supersonic over the entrie blade if the forward speed is subsonic. An integral equation for the required source distribution in the upwash region is derived. The potential for a point in the tip region can be obtained in terms of an integration of known source distributions over the blade surface only. The case of a twisted flat-plate blade with a symmetric tip is considered, and the pressure distribution over the tip region is calculated.

RESEARCH, RESEARCH FACILITIES

Wind Tunnels

VERRINGERUNG DES LEISTUNGSBEDARFS UND KONTINUIERLICHE REGELMÖGLICHKEIT FÜR DIE STRAHLGESCHWINDIGKEIT BEI TRIEBWERKSWINDKANÄLEN MIT FREISTRAHLMESSSTRECKE. Egbert Riester. ZFW, May, 1958, pp. 129-142. 23 refs. In German. Analysis of two types of wind tunnel designs for reducing the power requirements and for controlling the speed of wind tunnels with an open test section to test jet engines. One type is designed to run at sonic speeds and consists essentially of a nozzle and an external tube of slightly larger diameter; supersonic speeds are obtained with the other type. If the pressure behind the nozzle is too low, a second rhombus for measurement is formed in the free jet, with velocities and dimensions greater than

those of the nozzle rhombus. The velocity of flow can steadily be controlled by changing the back-pressure.

FLOW VISUALISATION TECHNIQUES APPLIED TO COMBUSTION PROBLEMS. E. F. Winter. RAeS J., Apr., 1958, pp. 268-276. Investigation of flow in continuous combustion systems by the method of direct flow visualization through transparent models in which water takes the place of air. The Thornton hydraulic flow apparatus and the experimental technique are described. Applications of the visualization technique and its limitations are discussed.

A SUMMARY OF EXPERIMENTS WITH SLOTTED TRANSONIC INSERTS IN THE NAVAL SUPERSONIC LABORATORY WIND TUNNEL. E. E. Covert. MIT NSL TR 207, Apr., 1958. 72 pp. 25 refs. Application of a set of transonic nozzle blocks to a normally supersonic tunnel under certain geometric restrictions. Calibration indicates that a useful Mach Number range between 0.5 and 1.3 and that the distribution is relatively uniform. The measurements indicate that for bodies with a blocking area up to 1.5% of the tunnel area, the slots deblock as expected by the theory. Models with a length of two-thirds of the tunnel height or less, and whose span is 45% of the tunnel height or less, may be tested on a developmental basis, provided a correction is made for a flow inclination.

ROTATING WING AIRCRAFT, HELICOPTERS

A REDUCTION METHOD FOR THE FORWARD TAKE-OFF OF A SINGLE ROTOR HELICOPTER. M. C. Neale. Gt. Brit., AAEE Rep. Res/297, Dec. 20, 1957. 23 pp. Presentation of a method for reducing observed helicopter take-off performance measurements to standard conditions and for estimating the effect of changes in wind speed, engine power, gross weight, and climb speed. The correction for wind changes is obtained from a consideration of the relative air velocities during the different stages of take-off. By the use of charts, changes in the other variables are related to changes in the value of the thrust/weight ratio which are used with further charts to determine the corrected flight path. A short illustration of a simple application of the method is made.

FLIGHT INVESTIGATION OF EFFECTS OF RETREATING-BLADE STALL ON BENDING AND TORSIONAL MOMENTS ENCOUNTERED BY A HELICOPTER ROTOR BLADE. L. H. Ludi. US, NACA TN 4254, May, 1958. 23 pp. Description of flight tests with a medium-size single-rotor helicopter, one blade of which was equipped with strain gages, to determine the effects of retreating-blade stall on the rotor blade bending and torsional moments during high-speed flight and pull-up maneuvers. Results indicate that in high-speed steady flight, retreating-blade stall can cause large increases in the periodic moments encountered by a helicopter rotor. The torsional moments and the vibratory bending moments in the highly stalled condition are three times as great as in the unstalled condition. The increased moments, particularly the torsional moments, cause increased periodic control loads and increased vibration in the helicopter control system, and thereby tend to restrict the high-speed operating limits of future helicopters. Pull-up maneuvers are found to produce essentially the same results as the high-speed steady-flight condition. The higher harmonics can contribute as much as the lower harmonics to increased vibration and increased periodic control loads in the highly stalled condition.

SPACE TRAVEL

ERROR ANALYSIS OF KEPLERIAN FLIGHTS INVOLVING A SINGLE CENTRAL FORCE FIELD AND TRANSFER BETWEEN TWO CENTRAL FORCE FIELDS. K. A. Ehricke. Navigation, Spring, 1958, pp. 5-23. Analysis of the effect of errors at cut-off on the flight path of an artificial comet. Motion in a central force field and escape from a planetocentric field into the heliocentric field are considered. Azimuthal error sensitivity increases with increasing speed. The heliocentric radial error sensitivity with respect to planetocentric errors is generally low. "Fast" orbits, which more or less steeply intersect the target orbit, are progressively less error sensitive the steeper the intersection becomes; simple "ballistic" flights to other planets require a degree of cut-off accuracy which is technically unfeasible, thus making correction maneuvers en route and upon approaching the target necessary.

LUNAR TRAJECTORY MECHANICS. L. G. Walters. Navigation, Spring, 1958, pp. 51-58. Discussion covering studies of the design and navigational aspects of translunar trajectories. A simple model of the earth-moon system, consisting of a planar representation of the Earth and Moon with each moving in a circular path about their common center of gravity, is used for design purposes. The role played by lunar motion in the guidance mission for a high-energy trajectory is described. It is shown that as the velocity increases toward the design value, the impact point moves up the face of the Moon; for higher values the impact points begin to retreat. The computation associated with the navigation problem is discussed.

AN ANALYTICAL SOLUTION FOR FLIGHT TIME OF SATELLITES IN ECCENTRIC AND CIRCULAR ORBITS. F. M. Perkins. Astronautica Acta, Fasc. 2, 1958, pp. 113-134. Derivation of the fundamental equations for the orbital lifetime and the altitude-time relationship of satellites in both circular and eccentric orbits. In the case of eccentric orbits, equations are developed for the rate of fall of perigee and apogee and the rate of approach to circular flight. The generalized solutions for orbital lifetime and the altitude vs. time relationships are compared with accurate results obtained from stepwise integration of the trajectory equations of motion by high speed digital computing machines. The analytical approach makes possible the rapid solution of large families of trajectories and illustrates general principles

of satellite orbital behavior. Use of the generalized curves for the analytical solutions is not limited to any one set of atmospheric density vs. altitude data. These plots are dimensionless and hence applicable to any units of measure.

STRUCTURES

PHOTOELASTIC INVESTIGATION ON PLATES WITH SINGLE INTERFERENCE-FIT PINS WITH LOAD APPLIED (a) TO PIN ONLY AND (b) TO PIN AND PLATE SIMULTANEOUSLY. H. T. Jessop, C. Snell, and G. S. Holister. Aero. Quart., May, 1958, pp. 147-163. Test results which indicate that when varying loads are applied to the pin or the plate, the effect of the interference is to produce a rise in the mean stress level at critical points on the hole boundary with a marked fall in the oscillatory stress. It appears that there is an optimum value for the "interference stress" for given applied loading conditions at which the endurance of the plate will have its highest value. When loads are applied simultaneously to pin and plate the critical stress on the hole boundary is found to be the mean of the stresses which would be produced by the total load applied separately to the pin and to the plate.

Bars & Rods

TORSION OF CYLINDRICAL AND PRISMATIC BARS IN THE PRESENCE OF PRIMARY CREEP. Sh. A. Patel and K. A. V. Pandalai. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 417 (AFOSR TN 58-303) [AD 154213], Apr., 1958. 7 pp. Analysis of the primary creep behavior of cylindrical and prismatic bars in which the deformations are caused by pure torsion. The creep problem is reduced to one in nonlinear elasticity by means of the elastic analog. The solutions are presented in closed-form.

Beams & Columns

IMPULSIVE LOADING OF PLASTIC BEAMS WITH AXIAL CONSTRAINTS. P. S. Symonds and T. J. Mentel. J. Mech. & Phys. Solids, May, 1958, pp. 186-202. Navy-sponsored analysis of the plastic deformation of simply supported clamped beams whose ends are prevented from displacing axially, and which are subjected to transverse impulsive pressure loading. It is shown that finite axial forces arise as soon as the beam acquires a finite deflection, and the transition is described from the initial simple beam behavior to the final stage where the deformations are governed primarily by catenary effects. When the loads are such that deflections are of the order of the beam thickness, or greater, the treatment as a simple beam becomes unrealistic, the deflections being greatly reduced by the action of the axial force. Curves are presented showing how the reduction depends on the span-depth ratio of the beam and on the intensity of loading.

A SUMMARY OF COMPRESSIVE-CREEP CHARACTERISTICS OF METAL COLUMNS AT ELEVATED TEMPERATURES. Appendix - COMPUTATION OF THE TIME-DEPENDENT TANGENT MODULUS FROM ISOCHRONOUS STRESS-STRAIN CURVES. R. L. Carlson and G. K. Manning. USAF WADC TR 57-96 [AD 151114], Apr., 1958. 57 pp. 22 refs. Review of creep buckling in columns, in which the column behavior prior to collapse is described and the column action at the time of buckling is interpreted in terms of stability. Solutions to creep buckling are discussed. It is concluded that in spite of certain limitations, Shanley's time-dependent tangent modulus method has several practical advantages over available analytical solutions. An application of the time-dependent tangent-modulus method to four structural metals indicates that estimates are consistently conservative for small values of column imperfection.

Cylinders & Shells

STABILITY OF CYLINDRICAL AND CONICAL SHELLS OF CIRCULAR CROSS SECTION, WITH SIMULTANEOUS ACTION OF AXIAL COMPRESSION AND EXTERNAL NORMAL PRESSURE. Kh. M. Mushtari and A. V. Sachenkov. (Prikl. Mat. i Mekh., Nov.-Dec., 1954, pp. 667-674.) US, NACA TM 1433, Apr., 1958. 15 pp. Translation. Determination of the upper limit of critical loads for cylindrical and conical shells under the combined action of uniform compression and isotropic external normal pressure. The differential equations for neutral equilibrium are solved for conical shells with simply supported boundaries. Approximate formulas are used for the determination of the critical external normal pressure with simultaneous action of longitudinal compression, and their accuracy is discussed.

Elasticity & Plasticity

A GENERAL THEORY OF UNIQUENESS AND STABILITY IN ELASTIC-PLASTIC SOLIDS. R. Hill. J. Mech. & Phys. Solids, May, 1958, pp. 236-249. Establishment of a sufficient condition for the uniqueness of the boundary-value problem set by given velocities on a part of the surface of a body and given nominal traction rates on the remainder. The solution, when it is unique, is characterized by an extremum principle. Stability under dead loading is also examined, and a criterion is proposed. This has a formal resemblance to the uniqueness criterion, but differs from it in a significant way when the body is partly plastic, so that stability and uniqueness need not be parallel properties.

Fatigue

A REVIEW OF THEORETICAL AND PRACTICAL METHODS OF ENSURING SAFETY FROM FATIGUE FAILURES IN AIRCRAFT IN FLIGHT. A. Hartman. (Netherlands, NLL Tech. Memo. M. 2008, 1957.) Gt. Brit., RAE Lib. Transl. 717, Feb., 1958. 45 pp. 60 refs. Review of published information about methods of experimental determination and calculation (extrapolation) of safety for passenger aircraft from catastrophic failure due to service fatigue loads. The study is concerned with the frequency distribution of the stresses

which occur, main attention being directed to the methods for testing and establishing safety factors. Consideration has been given to the significance of scatter, the strength remaining after a fatigue failure has appeared, the speed at which such a fracture propagates, and the possibilities of establishing by inspection whether an incipient fatigue crack has formed.

Plates

BUCKLING PHENOMENA OF STIFFENED PANELS. Syed Yusuff. J. Aero/Space Sci., Aug., 1958, pp. 507-514. 19 refs. Investigation of the instabilities involved in the design of stiffened panels forming compression surfaces. It is shown that three modes are largely encountered in compression panels - the first mode, associated with a long wavelength, is due chiefly to flexural deformation of the stiffeners; the second mode, which occurs in short wavelength, results mainly from the torsional restraining effects of the stiffeners; and the third mode is a combination of the first two modes. The presented theory is illustrated by the two commonly used methods of construction-namely, Z-stiffened panels of riveted construction and integral construction with unflanged stiffeners. An extensive analysis of test panels covering a wide range of configurations required to satisfy wing loading typical of modern aircraft is carried out.

Rings

PIERŚCIEŃ KOŁOWY POD WPŁYWEM DZIAŁANIA DANEGO OBCIĄŻENIA. Rozprawy Inżynierskie, Fasc. 1, 1958, pp. 12-21. In Polish, with summaries in English and Russian. Analysis of the problem of an isotropic circular ring subjected to an arbitrary load on the inner and outer circle. Using the relations between the value of an analytic function at any point of a ring region and its real and imaginary part on the inner and outer circle, equations are derived for the unknown analytic function $\Phi(z)$ and $F(z)$.

Sandwich Construction

ELASTIC INSTABILITY OF RECTANGULAR SANDWICH PANEL OF ORTHOTROPIC CORE WITH DIFFERENT FACE THICKNESSES AND MATERIALS. Appendix A - DETERMINATION OF NEUTRAL PLANE OF BENDING AND BENDING RIGIDITY. Appendix B - DERIVATION OF INTEGRALS OF STRAIN AND POTENTIAL ENERGY. Ch. C. Chang and I. K. Ebcioglu. Minn. U. Inst. Tech. Dept. Aero. Eng. SSR Rep. 1 (AFOSR TN 58-221) [AD 154122], Mar., 1958. 54 pp. 19 refs. Study of a sandwich panel which is simply supported and loaded with edge compression. The differential equations and corresponding boundary conditions are derived from the classical energy integral by means of the variational method. The solution is expressed in terms of the major buckling coefficient κ, which is essentially the ratio of the critical lateral buckling load to the critical cylindrical buckling load. A single family of curves is presented to show the behavior of κ, vs. $n\beta$ (the aspect ratio of the panel) for all geometrical and physical parameters of sandwich panels of current interest. The effect of different face temperatures on the maximum collapsing load can be interpreted from the theory.

Thermal Stress

THE FINITE TWISTING AND BENDING OF HEATED ELASTIC LIFTING SURFACES. Appendix A - EXPERIMENTAL APPARATUS AND METHODS. Appendix B - FUNCTIONS OF STATE OF AN ELASTIC SHELL ELEMENT. R. L. Blisplinghoff. ETH Inst. für Flugzeugstatik & Leichtbau, Mitteil. No. 4, 1958. 114 pp. 25 refs. Description of theoretical and experimental investigations on the behavior of elastic lifting surfaces under finite twisting, finite bending, and heating conditions. The scope of the study is confined to very long elastic surfaces of rectangular plan form. The theoretical approach is based upon the shallow shell theory of Marguerre, modified to include stiffened shells with temperature gradients over the surface and throughout the thickness. Thermal stresses are produced by the temperature gradients, and the modulus of elasticity is affected by the temperature level. A discussion of the equations of state of an elastic shell element is presented. The equations of equilibrium and compatibility and the boundary conditions are stated. A survey of the variational conditions of equilibrium and of the energy criteria for stability of heated elastic shallow shells is made. The theory is applied to two limiting cases of structural arrangement; solutions are presented in each case for the finite twisting and bending of the surface in the presence of the chordwise temperature gradients. A brief discussion of linearized shallow shell theory in the presence of temperature gradients is made. Experimental data are presented to confirm the theoretical results.

PLANE WAVES IN AN ELASTIC SOLID CONDUCTING HEAT. P. Chadwick and I. N. Sneddon. J. Mech. & Phys. Solids, May, 1958, pp. 223-230. 12 refs. Analysis of the propagation of waves in an isotropic thermoelastic solid. It is shown that the shear waves are not influenced by thermal effects but that two distinct dilatational waves do exist; one being similar in nature to a purely elastic longitudinal wave, but dispersed and attenuated by the medium, and the other being similar to a purely thermal wave.

THERMODYNAMICS

Combustion

SPECIAL ISSUE: STRÖMUNG UND VERBRENNUNG. BWK, June, 1958, pp. 257-299. 96 refs. In German. Contents: I - ZERSTÄUBUNG UND TROPFENGRÖSSENVERTEILUNG; II - FLAMMENBILDUNG, DIFFUSION UND VORGÄNGE IN DER GRENZSCHICHT; III - VERSUCHE AN MODELLEN UND GROSSAUSFÜHRUNGEN VON BRENNKAMMERN UND FEUERUNGEN. IV - EXTREME FÄLLE (KÜRZESTE ZEITEN, HÖCHSTE GESCHWINDIGKEITEN, HÖCHSTE TEMPERATUREN). Compilation of 14 technical papers covering: I - Atomization and drop size distribution: microphotographic investigation of fuel sprays in combustion

chambers; measurement and representation of drop size distribution in a spray; drop sizes with turbulent atomization. II - Flame formation, diffusion, and boundary layer phenomena: combustion of liquid and solid fuels as boundary layer problems; stabilized core of a flame held through a drag body; the length of the diffusion flame with gaseous as well as atomized liquid and solid fuels; influence of auxiliary-gas addition on the stabilization of turbulent flames. III - Experiments with models and on full size combustion chambers and furnaces: experiments on high output tubular and annular combustion chambers with different operating conditions and fuels; model experiments on combustion chambers. IV - Extreme cases (shortest times, highest velocities, and highest temperatures): ignition in the shock tube; kinetic theory of flows of dissociating gases; gasdynamic mixing phenomena and thrust increase through jet mixing.

INFLUENCE DU BLOCAGE DE LA VEINE PAR LES ACCROCHE-FLAMMES SUR LES LIMITES D'EXTINCTION. G. Matton. La Recherche Aéronautique, Mar.-Apr., 1958, pp. 3-11. 11 refs. In French. Investigation of the effect of throat blocking by flame holders on the extinction limits. Using values obtained experimentally for pressure on the holder, the velocity along the mixture flow and the height of the wake are introduced into the formulas, thus leading to the correlation of extinction limits. The method allows precise determination of the aerodynamic characteristics of long cylindrical or toroidal obstacles.

LONGITUDINAL COMBUSTION INSTABILITY IN A DUCT WITH OBLIQUE FLAME FRONT. Appendix - ONE-DIMENSIONAL OSCILLATIONS IN A SUPERSONIC DIFFUSOR. Marcel Vinokur. Lockheed Aircraft Missile Systems Div. Rep. LMSD-2346, Mar. 7, 1958. 118 pp. 25 refs. Reprint. Theoretical analysis of through-flow combustion leading to stability criteria applicable to realistic configurations. Only intrinsic, linear instability associated with longitudinal modes is considered. The flow equations are made quasi-one-dimensional in each gas region and are then combined, using the relations which hold accross the flame front. An explicit solution of the steady state equation is obtained for the case of small Mach Number. Equations governing small disturbances are obtained by means of a linearized, unsteady perturbation. The stability criterion can be expressed in a simple relation which exhibits the influence of each parameter that can be varied. The dependence of these parameters on the chamber configuration is presented graphically for a typical case. Various end conditions are investigated; the factors affecting the oscillations of heat release are considered. Results indicate that increasing the length of the flame region in general has a stabilizing effect, and that configurations whose ends are either "open" or "closed" are usually stable if the combustion covers over half the length of the chamber.

EVIDENCE FOR THE WRINKLED CONTINUOUS LAMINAR WAVE CONCEPT OF TURBULENT BURNING. J. K. Richmond, W. F. Donaldson, D. S. Burgess, and J. Grumer. (ARS 12th Annual Meeting, New York, Dec. 2-6, 1957.) Jet Propulsion, June, 1958, pp. 393-399. 17 refs. AFOSR-supported presentation of measurements on flames by means of an electronic probe, a photometer, and smoke photography to show that a turbulent flame may contain a wrinkled continuous laminar combustion wave. Long, vertical, cylindrical burners were used in all experiments, with three different diameters: 0.5625, 1.25, and 2 in. Results indicate that the distributed reaction zone model applies to conditions of incomplete burning within the flame brush. The transition from wrinkled wave to distributed reaction zone seems to correspond to the breakdown of full turbulent flames through the incidence of "holes."

BASIC CONSIDERATIONS IN THE COMBUSTION OF HYDROCARBON FUELS WITH AIR. Appendix - PHYSICAL AND COMBUSTION PROPERTIES OF SELECTED FUELS. Ch. C. Graves, D. W. Bahr, W. E. Scull, W. R. Mickelsen, F. E. Belles, C. C. Swett, G. L. Dugger, D. M. Simon, Melvin Gerstein, R. S. Brokaw, P. L. Blackshear, Jr., W. D. Rayle, R. L. Schalla, and R. R. Hibbard. US, NACA Rep. 1300, 1957. 259 pp. 604 refs. Supt. of Doc., Wash., $2.25. Study in which basic combustion research is collected, collated, and interpreted as it applies to flight propulsion. The following fundamental processes are treated: atomization and evaporation of liquid fuels, flow and mixing processes in combustion chambers, ignition and flammability of hydrocarbon fuels, laminar flame propagation, turbulent flames, flame stabilization, diffusion flames, oscillations in combustors, and smoke and coke formation in the combustion of hydrocarbon-air mixtures. Theoretical background, basic experimental data, and practical significance of flight propulsion are presented.

Heat Transfer

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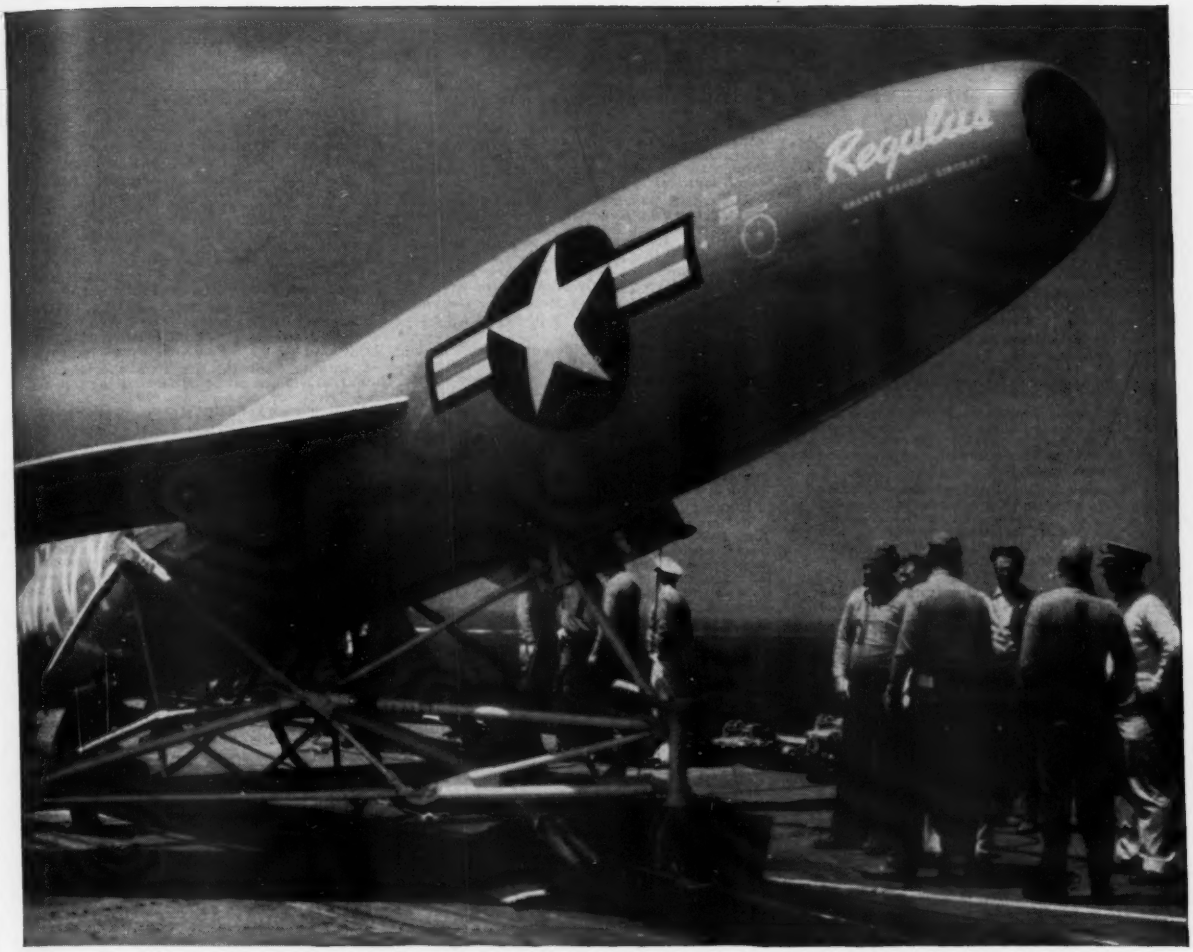

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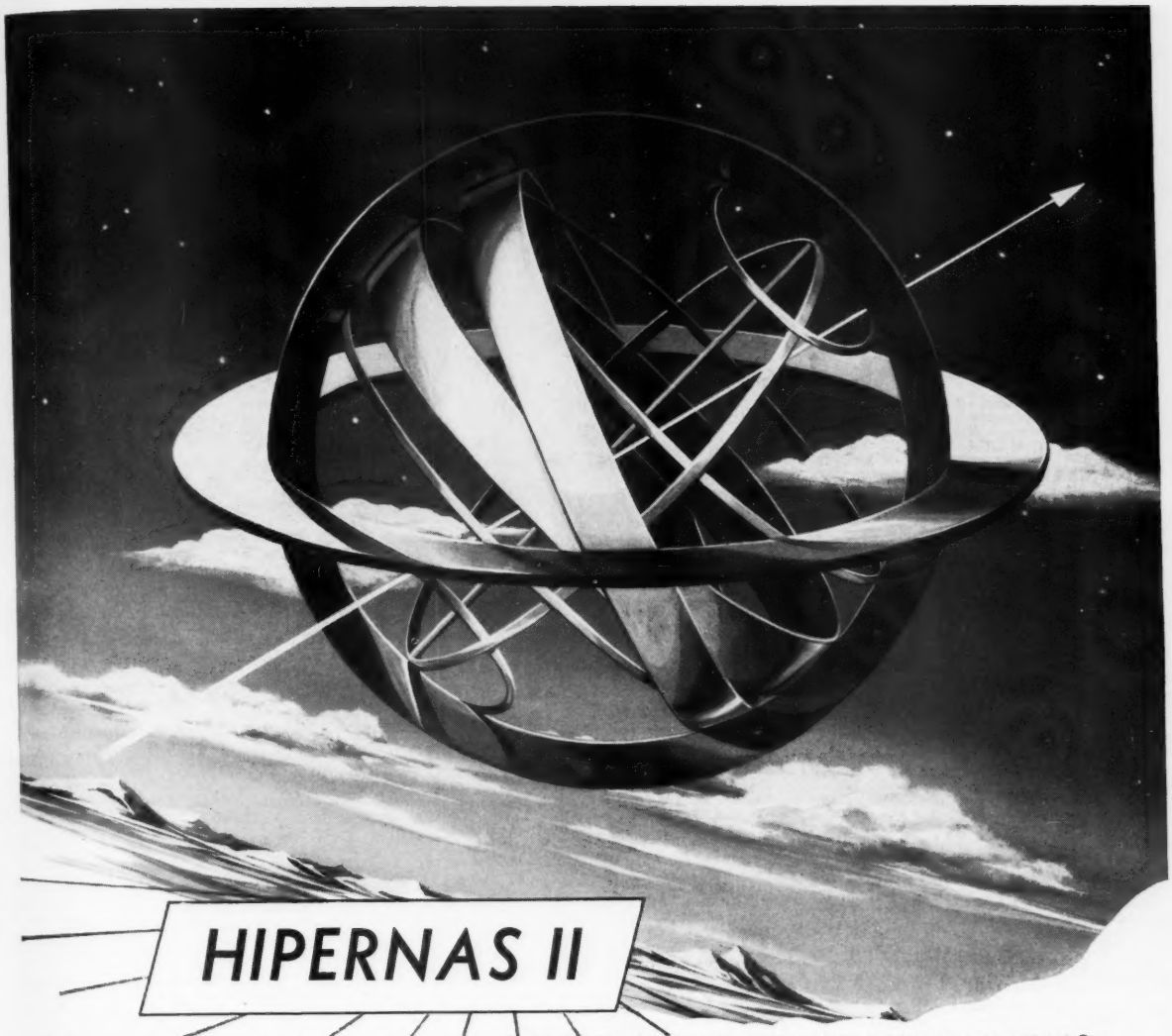

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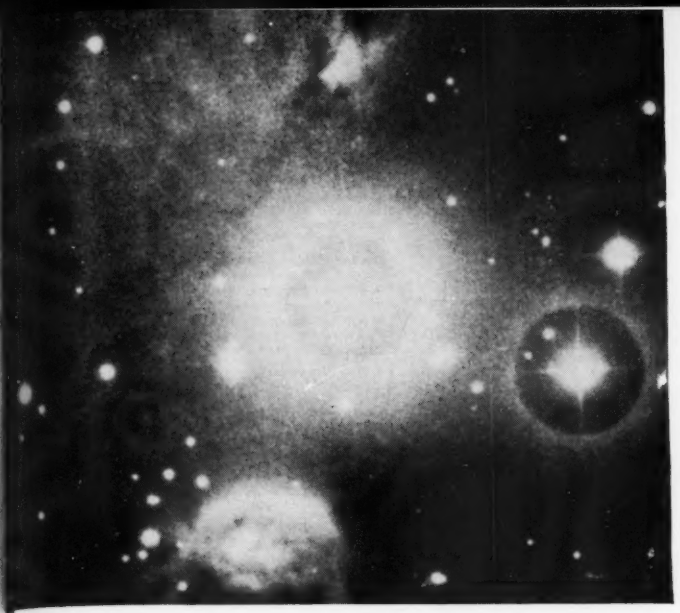

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FLIGHT IN THREE MEDIUMS

Several things set the Polaris apart from other outer space weapons in the ballistic missile category, for the Polaris program involves a wholly new concept of weaponry.

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3. It will be the first operational outer space missile to employ solid fuel as a propellant.
4. It will travel through three mediums in a single flight—water, air and outer space.
5. Its launching base—a submarine—is not fixed but a mobile vehicle.

OUTER SPACE PROGRAM

Very little can be said about the Earth Satellite program at this time except that its success will necessitate advancing the state of the art in all sciences.

The Earth Satellite Project is perhaps the most sophisticated outer space program to reach the "hardware" stage in the U.S. today.

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It is recoverable from flight by parachute to be flown again, permitting weapon system evaluation to be conducted at greatly reduced cost.

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Creep Behaviour of Circular Plates. B. Venkatraman and P. G. Hodge, Jr. (*Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 369, Apr., 1957.*) *J. Mech. & Phys. Solids*, No. 2, 1958, pp. 163–176. 13 refs. OSR-sponsored investigation.

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O Verificare Experimentală a Metodei Clasice de Calcul la Aripi din Lemn. A. Petre. *Stud. Cerc. Mec. Aplic.*, No. 4, 1957, pp. 1,303–1,308. In Rumanian. Experimental verification of the classical method for the calculation of wooden wings.

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Comments on "Characteristics and Sound Speed in Nonisentropic Gas Flows with Nonequilibrium Thermodynamic States." Harold Mirels. *J. Aero/Space Sci.*, July, 1958, pp. 460, 461.

Combustion

Evaluation of Flame Stability at High Reynolds Numbers. L. E. Bollinger. *Jet Propulsion*, May, 1958, p. 334. USAF-supported presentation of an equation for the velocity gradient under steady-flow conditions, applicable to either laminar or turbulent flow fields.

O Modelirovanii Protsessov Goreniia i Gazifikatsii Tverdogo Topliva. V. A. Smirnov. *AN SSSR Otd. Tekh. Nauk Izv.*, Jan., 1958, pp. 95–99. In Russian. Development of a method for simulating solid-fuel combustion and gasification processes.

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Vliianie Davleniia na Normal'nuiu Skorost' Rasprostraneniia Plameni. S. A. Gol'denberg and V. S. Pelevin. *AN SSSR Otd. Tekh. Nauk Izv.*, Feb., 1958, pp. 33–41. 33 refs. In Russian. Experimental investigation of pressure effect on the normal velocity of flame propagation, and survey of previously obtained results.

Heat Transfer

Determination of Free Convection Heat Transfer Properties of Fluids by Transient Response of a Copper Sphere. J. E. Boberg and P. S. Starrett. *Ind. & Eng. Chem.*, May, 1958, pp. 807–810.

How to Calculate Thermal Radiation from Hot Surfaces. G. V. Thompson. *Prod. Eng.*, May 31, 1958, pp. 116, 117. Presentation of charts to help pick surface finishes and temperature levels which dissipate heat to the atmosphere faster.

Stationary Convection in a Plane Liquid Layer Near the Critical Heat Transfer Point. L. P. Gor'Kov. (*Zhurnal Teoret. i Exper. Fiz.*, Aug., 1957, pp. 402–407.) *Sov. Phys.-JETP*, Feb., 1958, pp. 311–315. Translation. Presentation of the results of the determination of the symmetry and amplitude of the motion for supercritical gradients.

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Teplootdacha v Trubakh pri Laminarnom Rezhime Dvizheniia Zhidkosti s Uchetom Aksiial'noi Teploprovodnosti. D. A. Labuntsov. *AN SSSR Dokl.*, Feb. 21, 1958, pp. 1,118–1,120. In Russian. Analytical study of heat transfer in pipes for the case of laminar motion of a liquid, taking into account axial heat conduction.

VTOL & STOL

Ein Bewegungsrechner als Übungsgerät für Lotrecht-Start- und -Landevorgänge. Karl Zeilinger. *Luftfahrttechnik*, Apr. 15, 1958, pp. 116, 117. In German. Description of a training device designed for VTOL and STOL simulation.

Die verschiedenen Arten von Vertikalstartflugzeugen. W. Just. *Flugwelt*, May, 1958, pp. 321–328, 339. In German. Review of various VTOL types, covering the characteristics of helicopters, "rotor-planes" (such as the Rotodyne), convertiplanes, types with flow deflection, tilting propeller, and wing-flap systems, and ducted fan types. Aircraft with blown surfaces and those with direct thrust are also included.

The Fairey Rotodyne. D. M. Davies. *AHS Newsletter*, Mar., 1958, pp. 2–10. Discussion of the design features and development program for the 40-passenger rotary-wing aircraft.

Some Performance and Operating Characteristics of Convertiplanes. R. L. Lichten. (*SAE Natl. Aero. Meeting, Los Angeles, Oct., 1957.*) *AHS J.*, Apr., 1958, pp. 13–24. Analysis of the performance of four equivalent turbine-powered VTOL aircraft designs; the use of fixed vs. tilting wings is considered. The influence of disc loading on the characteristics of tilt-wing types during conversion is discussed.

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IAS News *(Continued from page 23)*

• **Amphenol Electronics Corporation** reports that construction has begun on a new manufacturing and office building in Broadview, Ill., at Cermak Road and 25th Avenue. The plant will have 110,000 sq. ft. of production facilities and 54,000 sq. ft. of office and cafeteria space, according to the company. Knud Knudsen has been appointed President, and George W. Oehlsen, Jr., General Manager, Danbury-Knudsen Division. Richard Steiger has been named General Manager, IPC Division.

• **Beech Aircraft Corporation** has announced the retirement of C. C. Pearson, Vice-President—Manufacturing, and the assignment of Frank E. Hedrick, Vice-President and a Director, to assume Mr. Pearson's duties. Also announced were the promotions of George W. Hostettler to Manager; A. L. Clark to Manager, Engineering, and Sales; and Frank W. McCabe to Special Assistant to Mr. Hostettler—all in the firm's Boulder Division.

• **Bendix Aviation Corporation,** Eclipse-Pioneer Division, has announced the purchase of a 117,000-sq.ft. building adjacent to the division's 100-acre Teterboro, N.J., installation to house electronic system engineering and specialized manufacturing facilities. . . .Louis F. Polk, Bendix Vice-President and group executive, has been awarded an honorary Doctor of Science degree from Miami University.

• **Boeing Airplane Company** has completed engine deicing and anti-icing tests on its 707 prototype using a special device that resembles a venetian blind type of catcher's mask mounted in front of the No. 3 engine. Designed by Boeing, the device reportedly sprayed water on the engine cowling. The company also announced the appointment of James E. Drummond, formerly with the Stanford Research Institute, to its Scientific Research Laboratories where he will direct research in the field of plasma physics. . . .The Transport Division rolled out its 100th KC-135 jet tanker-transport, the division announced.

Fairchild Engine and Airplane Corp. reports its F-27 commercial transport is the first jet-engine aircraft in airline service. It also is said by Walter Kidde & Co., Inc., to be the "first American-built plane to reach production which uses pneumatic systems to operate primary actuating systems." Kidde pneumatic systems power the main and hose landing gear, gear-up locks, nose wheel steering, tail bumper, and propeller brakes.

• **Chance Vought Aircraft, Inc.,** reports that it has placed in operation a new $450,000 research laboratory facility to test hydraulic fluid, jet fuel, and control systems at extremely high temperatures.

• **Douglas Aircraft Company, Inc.,** reports that dimensions are identical in all models of its DC-8 jet transport: 139 ft., 9 in. wing span; 150 ft., 6 in. length; and a tail 42 ft. from the ground. The first model is powered by four Pratt & Whitney JT3 (J-57) engines. Subsequent models will have JT4 (J-75) or Rolls-Royce Conway engines, according to the firm. All will have combination sound suppression and thrust braking mechanisms. The firm also reports that five official world aircraft climbing speed records have been broken with a Navy Douglas F4D-1 Skyray that reached 49,212.5 ft. in 2 min., 36.05 sec.

• **Eastern Air Lines, Inc.,** reports that it has received its last piston-powered aircraft, a Douglas DC-7B, and that the next aircraft it will receive is a Lockheed Electra.

• **Fairchild Engine and Airplane Corporation** reports that James H. Doolittle, NACA Chairman, was guest speaker at the dedication and first delivery ceremony of its F-27 prop-jet airliner. The aircraft went to West Coast Airlines.

• **The Garrett Corporation** has announced the appointment of Harry H. Wetzel as Manager, AiResearch Manufacturing Division, Los Angeles, Calif. Parker Bartlett and Stanley D. Whitaker have been named Sales Managers of the firm's AiResearch Manufacturing divisions in Los Angeles and Phoenix, Ariz., respectively.

• **General Dynamics Corporation,** Convair Division, reports that an all-metal, production-type replica of the 880 jet transport is nearing completion at San Diego, Calif. Karel J. Bossart and John C. Clark, both of Convair-Astronautics, have been appointed to the staff of R. C. Sebold, Vice-President — Engineering. Mr. Bossart, on leave as Technical Director, will act as Mr. Sebold's assistant for missile engineering. Dr. Clark, former Staff Assistant to the Astronautics Division Manager, will be Mr. Sebold's technical and scientific assistant. . . .Stromberg-Carlson Division has named Kenneth M. Lord Director of Engineering, Electronics Division. . . .Electric Boat Division reports that keels for two more atomic submarines have been laid down. . . .General Atomic Division says the AEC has selected its TRIGA, a newly developed, multipurpose nuclear research reactor, to provide short-lived radioisotopes for the U.S. Life Sciences exhibits at the Second International Conference on the Peaceful Uses of Atomic Energy in Geneva, September 1–13.

• **General Electric Company,** Aircraft Gas Turbine Division, has formed a Commercial Engine Operation section with full responsibility for acceptance of engineering design and for production, marketing, and servicing of large commercial turbine engines. Neil Burgess has been named Manager of the section. . . .Defense Electronics Division, Heavy Military Electronic Equipment Department, is building a new test facility for the ballistic missile radar system that the firm is also building. The division's Light Military Electronic Equipment Department is producing the

Douglas Aircraft Company's entry into the jet-powered transport field recently had its maiden flight from the firm's Long Beach, Calif., plant. The DC-8 has been ordered by 17 airlines of the world, the firm reports. It is capable of carrying from 118 to 176 passengers. Further statistics are reported in the Douglas item on this page.

armament system fire controls and flight controls for the Republic F-105, the firm announced.

• **General Precision Equipment Corporation,** Link Aviation, Inc., reports that construction has been completed on research and development facilities at Palo Alto, Calif.

• **Kelsey-Hayes Company** has announced the appointment of Adolph E. Palty as Supervisor, Alloy Development and Evaluation, Utica Metals Division. Kuang Lu Cheng has been appointed Associate Director of Research for the division, it was also announced.

• **Lear, Incorporated,** has announced the appointment of John F. Harrigan as Manager, Grand Rapids Division, Dayton, Ohio, Area Office. . . .LearCal Division has named Walton B. St. John Sales Manager for Airframe Accounts—Executive Aircraft Equipment.

• **Lockheed Aircraft Corporation** has announced the election of Vernon A. Johnson as Vice-President. He is Director, Corporate Outside Offices. . . .Missile Systems Division has announced installation of a new $1.5 million electronic brain at its Palo Alto, Calif., computing center. . . . The firm reports its JetStar utility jet transport has completed a 3,105 statute mile nonstop nonrefueled flight during testing at Edwards AFB. Also reported were two world's records for its F-104A Starfighter: a speed record of 1,404.19 m.p.h. and an altitude record of 91,249 ft.

• **The Martin Company** has announced managerial changes at its Orlando, Fla., guided missile and electronics center: Sidney Stark was named Operations Manager, Pershing missile, and Henry M. Watts was appointed Chief Engineer. Named to other jobs were E. R. McDonald, Controller; C. A. Blaney, Director of Procurement; and A. R. Bergstrom, Director of Plant Facilities.

• **North American Aviation, Inc.,** Atomics International Division, reports that Chauncey Starr, North American Vice-President and Atomics General Manager, has been elected President, American Nuclear Society. . . .Autonetics Division has announced that it is developing and fabricating the guidance and control equipment for the GAM-77 missile program. Peter A. Kreider has been appointed Project Manager in this area.

• **Pan American World Airways, Inc.,** has announced the appointment of James D. Leet as New York District Sales Manager.

• **Pesco Products Division, Borg-Warner Corporation,** has named Robert E. Kemelhor Manager, Future Product Planning and Development, and has appointed Edward G. Howard, Washington, D.C., Representative.

• **The Ramo-Wooldridge Corporation's** Space Technology Laboratories has designed and built a new, small-size Mach 3 variable density research wind tunnel for magnetoaerodynamic boundary-layer research studies for the USAF Ballistic Missile Division (ARDC), the firm announced.

• **Republic Aviation Corporation** reports that it has delivered the first production model of the F-105 Thunderchief to the Air Force. The company also announced sale of its first Alouette II jet-powered helicopter to Inlet Airways of Alaska.

• **Solar Aircraft Company** has named Ben Dundee Industrial Sales Representative, northeast district.

• **Thompson Products, Inc.,** will open its West Coast Laboratory full-scale missile systems ground test facility for visits by delegates to the Western Electronics Show and Convention later this month.

• **Union Carbide Corporation. . .**Linde Company reports that it will erect a new oxygen plant and pipeline system—a 1,000-ton-per-day plant—to serve four U.S. Steel plants in the Pittsburgh area. Another 300-ton-per-day plant is to be built at Pittsburg, Calif., for use by aero-space industry firms.

• **United Aircraft Corporation. . .**Pratt & Whitney Aircraft division has announced the promotion of Ross H. Begg, Jr., to Assistant to the General Manager. . . . Sikorsky Aircraft reports that its helicopter automatic stabilization equipment has been certified by the CAA for use in commercial helicopters.

• **Vertol Aircraft Corporation** has announced the election of Hamilton W. Lord as Treasurer and John A. O'Hara, Jr., as Secretary of the firm. Karl Fritsch has been named Chief Development Engineer. Appointed to jobs in the new International Division were H. Stever Tremper, Manager; Richard S. Leslie, Manager, Service Department; Kenneth H. Hemberger, Acting Manager, Commercial Department; Lloyd Sloan, Manager, Sales Engineering; and Philip M. Egan, Export Administrator.

• **Vickers Incorporated. . .**Aero Hydraulics Division has named W. S. Bobier Chief Engineer, Detroit Activity. The division also appointed Walter K. Deacon Chief Engineer, Torrance Plant; he replaces Edward I. Brown who was named Director of Engineering, Machinery Hydraulics Division.

• **Vitro Corporation of America. . .**Laboratories Division has installed a Bendix digital electronic computer for general engineering research at its Silver Spring, Md., facility. The company also announced the appointment of Robert W. Dillon as West Coast Sales Representative for the Vitro Weapon Systems Group. T. William Hefferan, Jr., has been named Dayton Representative for the firm.

IAS News — IAS Sections

Chicago Section

A Summary of Meetings

Members visited Argonne National Laboratory's reactor facilities on April 23.

They heard a description of the work at the facility and saw films of the Fast Reactor Program, the Argonaut Reactor, and the Experimental Boiling Water Reactor.

▶ The annual student meeting was held at Illinois Institute of Technology on March 19. **William J. Cochran,** Project Coordinator, Grumman Aircraft, spoke before 100 members and students on **"Flight Testing High-Performance Aircraft in the Transonic and Supersonic Speed Ranges."**

He discussed flight and aerodynamic characteristics and phenomena associated with extreme speed ranges of modern jet fighters. He also described the sensation of weightless flight.

▶ **Angus L. Wynn** spoke on **"Turbojets—Speedy, Simple, Safe, and Sure"** at the February 5 meeting. Mr. Wynn is Supervisor, X279 Project Evaluation, General Electric Aircraft Gas Turbine Division. He described the design simplicity, high-speed capability, safety features, and operational reliability of turbojets.

▶ **Vic Canfield,** Dayton Representative, Ryan Aeronautical Co., described development and flight-test operations of the X-13 Vertijet.

He said it was developed to study aspects of VTOL and was not intended to be tactical. He illustrated his talk with movies showing the full operational sequence of the X-13.

J. S. ISLINGER, *Secretary*

Kansas City Section

USAF Missile Progress Report by General Demler

Major Gen. Marvin C. Demler, USAF, spoke on **"The Air Force Guided Missile Program—A Progress Report"** before some 250 members of this Section who were joined by their SAE counterpart on April 24 (see photo, p. 112).

General Demler, Deputy Commander for R&D, ARDC, updated his earlier report given in January at the IAS 26th Annual Meeting. He used slides and movies to illustrate the talk and was assisted by his aide, Major Joseph DuBois.

J. R. MACPHERSON, *Secretary*

Rocky Mountain Section

Air Force Academy Courses Described

Two speakers were featured at the April 17 meeting—**Lt. Col. G. C. Clementson** and **Capt. J. R. Plitt,** both of the USAF Academy. They spoke on **"Science and Engineering Curriculum at the Air Force Academy"** and **"Facilities at the Air Force Academy—Permanent Site."**

Lt. Colonel Clementson, Professor of Aerodynamics at the school, presented a detailed examination of specific aspects of the curriculum—e.g., the recently added Astronautics Department courses. He used slide-projected charts for illustration.

Captain Plitt, also using slides, described Academy facilities. He is special assistant to the Superintendent.

D. A. KNOWLTON, *Secretary*

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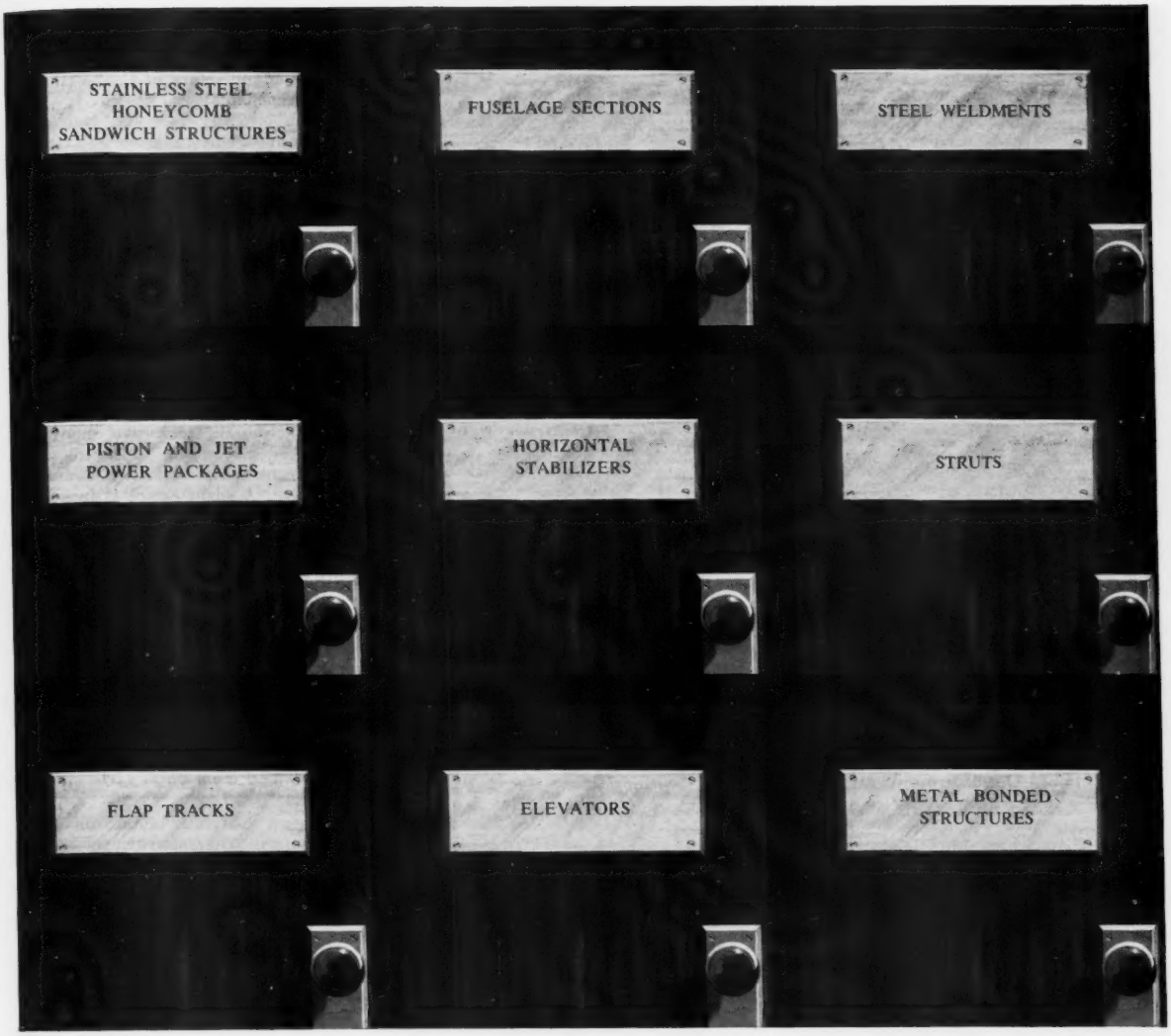

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Some 250 members and guests turned out to hear Major Gen. Marvin C. Demler present "The Air Force Guided Missile Program—A Progress Report" at the April 24 Kansas City Section meeting. IAS members were joined by their SAE counterparts for the meeting.

San Antonio Section

ICBM Development Traced by Bossart

"The History and Importance of the ICBM" was discussed by **Karel J. Bossart** at a meeting commemorating Armed Forces Week on May 16. Mr. Bossart is Technical Director, Convair-Astronautics.

He outlined the progress of air weapons to the Atlas ICBM, referring to them as deterrents to an all-out war. Problems encountered in designing the basic structure of missiles, the mixing of fuels, and missile guidance were also discussed. Mr. Bossart illustrated his talk with color slides of an Atlas launching.

During the business portion of the meeting, Major Marvin Larsen was appointed Second Vice-Chairman *pro tem*. Additions to various committees also were announced.

ROBERT R. PERRY, *Secretary*

Tulsa Section

Student Competition Sponsored by Section

A student paper competition, sponsored by the Section and having no relationship to the Minta Martin Conferences, was held on March 11.

Judges were William Lawrence, American Airlines, with Russell Brown, Frank Dickey, and Edward Rutowski, Douglas Aircraft.

First prize was won by B. T. Leland, University of Tulsa, for a paper on "The Jet-Propelled Propeller."

Allen White, University of Tulsa, won second prize for his paper "An Investigation of Rocket Engine Cooling by the Evaporation of Liquid Oxygen."

Armen Melikian, Oklahoma State University, won third prize for a paper titled "Beyond the Cradle."

ALLAN M. MCCASKILL, *Chairman*
Student Activities Committee

Wichita Section

Solid Propellant Cast Rockets

"The Manufacture of Cast Composite Solid Propellants" was described by **D. S. Nauman** on May 14. Mr. Nauman is Propellant Plant Manager, Longhorn Division, Thiokol Chemical Corporation.

He covered the construction of a cast solid rocket and listed several missiles using solid rockets for propulsion. He said the name Thiokol comes from the Greek words for gum and sulphur. The material sticks to almost everything and is widely used as a building construction adhesive.

Mr. Nauman showed slides of various shape changes and pointed out the manner of burning to obtain a particular thrust-time relationship. The rockets, viewed down the nozzle, look like snowflakes, four-leaved clovers, or "n-leaved" roses. This stoichiometric ratio is not obtained purposely. A slight excess of fuel serves as a coolant for the exhaust nozzle.

Newly elected Section officers are Milford F. Vanik, Chairman; Howard W. Smith, Vice-Chairman; Everette L. Cook, Secretary; and Harry R. Clements, Treasurer.

H. W. SMITH, *Secretary*

✦ ✦ ✦

Water-Based Aviation Award

(Continued from page 15)

flight tests, analytical studies of overall hydrodynamic characteristics of various seaplane configurations, specific tests and studies of seaplane stability, strut, used for hydroski and hydrofoil support and sea states affecting seaplane operations.

He also has contributed several reviews and summaries of state of the art seaplane development and, at the 1948 International Congress of Applied Mechanics in London, gave a paper on the hydrodynamic characteristics of flying boats. Besides his work at BuAer, he also has been active in promoting basic research projects within industry, universities, and other Government agencies.

Mr. Locke was born in 1913, attended public schools in Forest Hills and Garden City, N.Y., Massachusetts Institute of Technology, and Stevens, from which he was graduated in 1937.

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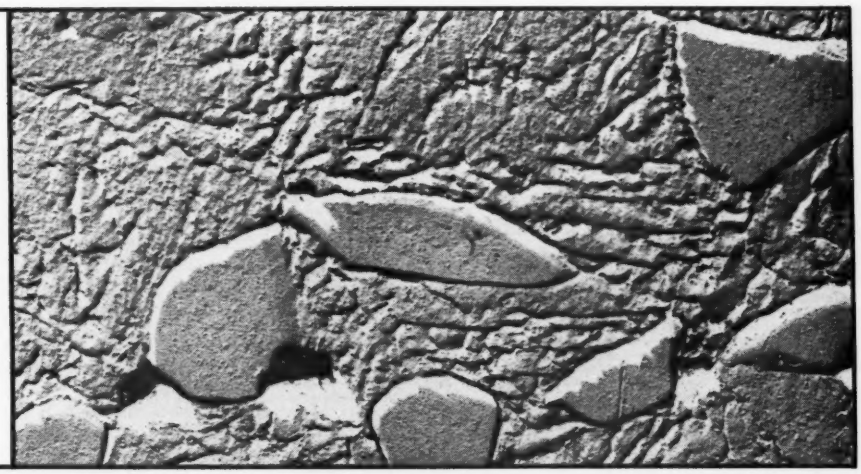

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AE or ME with 3-5 years flight test experience. Familiar with instrumentation, data analysis, system testing & mission planning.

▶ EXPERIMENTAL DESIGN/TEST

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Modern Airmanship. Edited by Neil D. Van Sickle. Princeton, N.J., D. Van Nostrand Co., Inc., 1957. 862 pp., illus., diagrs., tables. $9.75.

Written for civilian as well as military airmen, this highly comprehensive work on all the basic aspects of modern flying is the joint effort of 19 authorities, under Colonel Van Sickle's direction, to bring together in one volume the lessons learned from half a century of commercial and military aviation.

The core of the book is what the airman needs to know about the atmosphere and its attendant weather, aerodynamics and the theory of flight, the structure and propulsion of his craft, aircraft instruments and flight techniques, instrument flying, and air navigation. The new developments in high-performance, supersonic, and jet-engine flying are fully developed, including the important areas of Arctic and wilderness flying which are special theaters calling for specific skills on the part of the airman.

Other chapters discuss the classification and characteristics of modern aircraft types, the more important medical aspects of flight, and the development and operation of rotary-wing aircraft. Finally, a group of chapters deals with ground services—the layout of airports, servicing and maintenance, and the official organizations that control air traffic and perform rule-making and investigative functions.

AIRPLANES

Landing Gear Design. H. G. Conway. Published Under the Authority of The Royal Aeronautical Society. London, Chapman & Hall, Ltd.; New York, The Macmillan Co., 1958. 342 pp., illus., diagrs., tables. $12.

Since landing gear design combines the best in mechanical and structural engineering and requires high precision in manufacture, particular attention is given in this textbook to practical design advice which should be of value to both aeronautical and student engineers. Commencing with chapters on the purpose and arrangement of landing gears, problems of energy absorption, tires, wheels, and brakes are next considered. The general layout and detail design of landing gear are then described, with later chapters on shock absorbers, retraction and stressing. The final chapter deals with unorthodox landing gear (snow skis, skid landing gear, helicopter landing gear, etc.), and the book concludes with an index of aircraft types.

The author is Director and Chief Engineer, Short Brothers and Harland Ltd., Belfast.

AIRPORTS

Apron Requirements for Turbine Powered Aircraft; A Reference Document of Principles and Guidance Material for Use by Those Concerned with Airport Planning. Montreal, International Air Transport Association, January, 1958. 57 pp., diagrs. $0.75.

Although this document is supplementary to *Airport Buildings and Aprons*, an IATA handbook published in July, 1956, its aim is to present information relevant particularly to turbine-powered aircraft operations on the apron, and therefore it should not normally be necessary to refer back to the earlier work. The present document was compiled by a group of specialists representative of a variety of airline interests—technical, operations, cargo and passenger traffic and facilitation—working under the overall direction of the Technical Committee of IATA. Among the material it contains which will be of interest to airport owners, operators, and administrators and to municipal and national government officials are the following sections:

General Considerations: Factors affecting blast from jet engines (blast levels, effects of blast, means for countering blast effect), the effects of heat, fumes, factors affecting noise, noise level tests, apron clearing, fuel spillage, and pavement markings.

Apron Systems and Requirements: Passenger convenience and comfort; parking in relation to blast, heat, and noise; terminal configuration and apron system layout; aircraft loading and servicing points; turning circles; clearance between aircraft and buildings; guide lines; docks and mechanical conveyance systems; mobile servicing equipment; apron occupancy time; and assignment of stands.

Fixed Servicing Installations: Fuel, electrical ground power; ground communications; lighting and water; compressed air for starting; and cabin air conditioning.

Apron Load Handling Facilities: Principles governing the flow of passengers; baggage, freight, and mail; consideration of conveyance systems for moving aircraft; and passengers, baggage, and freight on the apron.

ASTRONOMY

The Exploration of Space by Radio. R. Hanbury Brown and A. C. B. Lovell. New York, John Wiley & Sons, Inc., 1958. 207 pp., diagrs., illus. $6.50.

Although the phenomena of radio emission from space was discovered over a quarter of a century ago, the possibilities of the investigation of the universe by radio methods were not fully realized until the second World War when many scientists were brought in close touch with radar. The initial postwar development of radio astronomy occurred primarily in England and Australia, but the discovery in 1950 of the radio emission from the neutral hydrogen gas in interstellar space aroused considerable interest in Holland and the United States, and the subject is developing with great rapidity.

The present book surveys the whole field of radio astronautical studies, including the radio echo, or radar, techniques for the investigation of various aspects of the solar system, as well as the receiving techniques used to study the solar and the galactic and extragalactic radio emissions.

Mr. Brown is Reader in Radio Astronomy, University of Manchester, while Mr. Lovell is Professor of Radio Astronomy at the same institution and Director of the Jodrell Bank Experimental Station.

Contents: (1) The Astronomical Background. (2) Some Properties of Radio Waves. (3) Techniques of Radio Astronomy. (4) Galactic and Extragalactic Radio Emissions. (5) The Hydrogen Line. (6) The Scintillation of the Radio Stars. (7) Solar Radio Waves. (8) Meteors. (9) Radio and the Aurora Borealis. (10) Radio Investigations of the Moon Planets and the Earth Satellite. (11) The Jodrell Bank Radio Telescope.

CONTROL THEORY

Analysis and Control of Nonlinear Systems; Nonlinear Vibrations and Oscillations in Physical Systems. Y. H. Ku. New York, The Ronald Press Co., 1958. 360 pp., diagrs. $10.

This book is intended to provide electrical and mechanical engineers, physicists, and applied mathematicians with a practical and up-to-date account of the available techniques for the analysis and control of nonlinear physical systems. Both analytical and topological methods of solving nonlinear differential equations are presented, covering both mechanical vibrations and electrical oscillations, while physical examples in both mechanical and electrical systems which involve nonlinearities are worked out in detail. The reader is expected to utilize the analog between mechanical and electrical systems so that a given solution for a problem in a mechanical system can be utilized to solve a similar problem in the electrical system, and vice versa; other physical systems, such as hydraulic and acoustic, can be studied in like manner. A feature of the book is the new approach to third- and higher-order nonlinear differential equations, based on the author's method of space trajectory in n dimensions, which extends the phase-plane method to the phase-space.

Mr. Ku, who is Professor of Electrical Engineering, University of Pennsylvania, includes in his work numerous problems in nonlinear circuit analysis and a bibliography containing more than 700 references.

Thinking by Machine; A Study of Cybernetics. Pierre de Latil. Translated by Y. M. Golla. Boston, Houghton Mifflin Co., 1957. 353 pp., illus., diagrs. $5.50.

The implications of the general concept of feedback, or retroaction, and its relation to cybernetics is the chief subject of discussion in this work by a noted French scientific author who writes primarily to give the layman an understanding of the technological revolution expected to follow the wide-scale adoption of self-governing machines. Mr. de Latil describes the principles that make the most complex automatic machines possible, as well as the fundamentals of their construction, but—more importantly—concentrates on those aspects of thinking and human experience which enabled a small nucleus of scientists to unite two spheres which were formerly independent or even opposed—mathematics and physiology. From this marriage of two separate systems, cybernetics was born, and the book attempts to show that not a single field of science is likely to remain unaffected by the mathematical reasoning and experiments now employed in bridging the scientific and philosophical gap between machines and life.

DICTIONARIES

Castilla's Spanish and English Dictionary. Vol. 1, English-Spanish; Vol. 2, Spanish-English. New York, Philosophical Library, 1958. Vol. 1, 1611 pp., tables; Vol. 2, 1137 pp., tables. $45 the set.

Compiled by a panel of engineers, technologists, lexicographers, legal and industrial experts, and translators, this dictionary is intended to serve those in industry, business, or engineering who have occasion to employ both Spanish and English terms that have an immediate technical connotation. In general, the words appearing in this work are from the fields of engineering technology (although certain terms from the physical, chemical, and biological sciences which are of importance to engineers and technologists have also been included) and are those used in everyday technical language, not special or obsolete terms. Except in cases of ambiguity, definitions do not show the field to which the terms belong nor are the terms cross-referenced. When dealing with words that are untranslatable, a brief explanation is given; also, the most important abbreviations are included at the head of each letter. The dictionary closes with tables giving the main equivalents of the metric and the American and English systems of measurements.

ELECTRONICS

Television in Science and Industry. V. K. Zworykin, E. G. Ramberg, and L. E. Flory. New York, John Wiley & Sons, Inc., 1958. 300 pp., illus., diagrs., tables. $10.

In this book the authors seek to explore the function of television as an extension of human sight—variously called closed-circuit or industrial television to distinguish it from the broadcast function—and to describe the tools that have been developed to realize it. Analyzing both equipment and applications, they discuss closed-circuit color television and the improvements achieved by transistorization, stereo television, specialized television methods in research (including aeronautical research), and television microscopy. The principal fields of application of television in industry, research, medicine, education, commerce, military affairs, and the home are outlined.

The Encyclopaedia of Radio and Television; A Complete Alphabetical Reference to All Aspects of Modern Radio Technology. 2nd Ed. J. H. Reyner, Technical Consultant. New York, Philosophical Library, 1958. 736 pp., diagrs., tables. $12.

This encyclopedia, which is the work of 13 authorities and contains over 3,000 entries and nearly 800 illustrations, has been prepared with a view to providing easy and useful reference to all the main aspects of modern radio and television engineering. Among the subjects it covers are the fundamentals of radio; transmitting and receiving theory and practice, including broadcasting; television techniques; radar; communication systems; components; measuring instruments; and electrical machinery and power supplies. A separate reference section contains a number of nomograms, a wide range of formulas with worked examples, and other data.

EQUIPMENT

Fluid Pressure Mechanisms. H. G. Conway. 2nd Ed. New York, Pitman Publishing Corp., 1958. 235 pp., diagrs. $6.75.

This work deals with the mechanism of fluid pressure equipment and systems—i.e., hydraulic and pneumatic machinery. It is not concerned with detail design or constructional features of the equipment, but with the essential principle of the various devices, how they work, and how they

differ from each other. The scope of the book covers hydraulic, pneumatic, and compressed gas systems of high, medium, and sometimes low pressure.

The revised edition (1st Ed., 1949) contains new diagrams, as well as new material on slide valves, jacks with force limitation, special couplings, three-position jack systems, and synchronization systems. Perhaps the most important change is a substantial revision of the chapter on servosystems to bring it more into line with modern servo practice.

FLUID MECHANICS

Fundamentals of Gas Dynamics. Edited by Howard W. Emmons. (High Speed Aerodynamics and Jet Propulsion, Vol. 3.) Princeton, N.J., Princeton University Press, 1958. 749 pp., illus., diagrs., tables. $20.

In this volume, contributors from the gas dynamics field present a thorough treatment of those aspects of gas dynamics essential to the study of high-speed aerodynamics and jet propulsion. The topics under discussion include the equations of gas dynamics and their development in forms most useful to aerodynamicists; one-dimensional treatment of both steady and nonsteady gas dynamics; hydrodynamic discontinuity phenomena, covering gas dynamic problems associated with shock waves and other considerations; shock-wave interactions; and condensation phenomena in high-speed flows.

A section devoted to the gas dynamics of combustion and detonation deals with aerothermodynamic problems of combustion, flow discontinuities associated with combustion, and the gas dynamical aspects of combustion.

The volume closes with an analysis of the flow of rarefied gases in which the regimes of slight and extreme rarefaction are examined and an account is given of the experimental data available in the slip and transition regimes for various geometries of aerodynamic interest.

1958 Heat Transfer and Fluid Mechanics Institute; Held at University of California, Berkeley, Calif., June 19–21, 1958; Preprints of Papers. Stanford, Calif., Stanford University Press, 1958. 264 pp., illus., diagrs., tables. $8.50.

Contents: Survey: Theoretical Aerothermodynamics, Howard W. Emmons. Fluid Dynamics: Effect of a Contraction on Turbulence and Temperature Fluctuations, R. R. Mills, Jr., and S. Corrsin. Experimental Investigation of Turbulent Pipe Flow with Coolant Injection, S. W. Yuan and A. Barazotti. An Analysis of the Energy Separation in Laminar and Turbulent Compressible Vortex Flows, Robert G. Deissler and Morris Perlmutter. Dynamics of Reactive Fluids: Mass Transfer Cooling with Combustion in a Laminar Boundary Layer, J. P. Hartnett and E. R. G. Eckert. Considerations Related to the Quenching of Flames with Simple Kinetics, Melvin Gerstein and A. E. Potter, Jr. Wave Propagation in a Reacting Mixture, Boa-Teh Chu. Criteria for Thermodynamic Equilibrium in Gas Flow, Morton Rudin. Compressible Couette Flow with Diffusion of a Reactive Gas from a Decomposing Wall, Eldon L. Knuth. Heat Transfer: Boundary-Layer Transition and Heat Transfer in Shock Tubes, R. Hartunian, A. Russo, and P. Marrone. Heat Transfer and Friction in Swirling Turbulent Flow, Frank Kreith and David Margolis. Turbulent Heat Transfer on Highly Cooled Blunt Nosed Bodies of Revolution in Dissociated Air, Peter H. Rose, Mac C. Adams, and Ronald F. Probstein. Natural Convection Heat Transfer in Liquids Confined by Two Horizontal Plates and Heated from Below, Samuel Globe and David Dropkin. Magnetohydrodynamics: Drag of a Sphere Moving in a Conducting Fluid in the Presence of a Magnetic Field, K. P. Chopra and S. F. Singer. On a Class of Magnetic Laminar Boundary Layers, Paul S. Lykoudis. Hypersonics: Exploratory Studies of a Spiked Body for Hypersonic Flight, S. M. Bogdonoff and I. E. Vas. Results from Aerodynamic Studies of Blunt Bodies in Hypersonic Flows of Partially Dissociated Air, A. J. Vitale, E. M. Kaegi, N. S. Diaconis, and W. R. Warren. The Laminar Hypersonic Heat Transfer on a Blunt Body According to the Integral Method, Paul A. Libby. The Two-Phase Hypersonic Laminar Boundary Layer—A Study of Surface Melting, S. M. Scala and G. W. Sutton. Thermal Analyses of Stagnation Regions with Emphasis on Heat Sustaining Nose Shapes at Hypersonic Speeds, A. J. Hanawalt, A. H. Blessing, and C. M. Schmidt. Survey: Magnetohydrodynamics, Rolf K. Landshoff.

Fluid Mechanics. Victor L. Streeter. 2nd Ed. New York, McGraw-Hill Book Co., Inc., 1958. 480 pp., illus., diagrs., tables. $7.50.

Part One of this two-part work explains the properties of fluids, fluid statics, and the underlying framework of concepts, definitions, and basic equations for fluid dynamics. Also included, with illustrations and elementary applications, are a treatment of viscous effects and the effects of density changes on fluid flow, a discussion of two-dimensional flow of an ideal fluid, and a presentation of dimensionless parameters. *Part Two* deals with the important fields of application of fluid mechanics: turbomachinery, measuring of flow, closed conduit and open-channel flow, and automatic fluid controls.

The author is Professor of Hydraulics, University of Michigan, and has organized the material primarily as a beginning undergraduate course in fluid mechanics.

GRAPHICS

Graphic Science; Engineering Drawing, Descriptive Geometry, Graphical Solutions. Thomas E. French and Charles J. Vierck. New York, McGraw-Hill Book Co., Inc., 1958. 758 pp., illus., diagrs. $8.50.

The three portions of this text deal with engineering drawing—the fundamentals of projection and the communication phase; descriptive geometry—the solution of space problems of points, lines, planes, and surfaces; and graphical solutions—the solution of mathematical problems of particular interest to engineers. The book stresses not only the communication phase, but also the methods and procedures that will accomplish graphic determination and computation. In place of subjects such as jigs and fixtures, gears and cams, architectural and structural drawing, there is a complete coverage of descriptive geometry—points, lines, planes, intersections, curved lines, and curved and warped surfaces. In addition, vector geometry, graphical solutions, functional scales, nomography, empirical equations, and calculus are covered.

INSTRUMENTS

The Gyroscope; Theory and Applications. James B. Scarborough. New York, London, Interscience Publishers, Inc., 1958. 257 pp., illus., diagrs., tables. $6.50.

The aim of this book is to give a systematic and reasonably complete treatment of the mathematical and mechanical aspects of the gyroscope and its more important applications. Since vector methods are employed in this treatment without, however, assuming a knowledge of these methods on the part of the reader, the first chapter is devoted to the exposition of the amount of vector analysis needed in the subsequent chapters. Constructional details are not entered into except insofar as they may aid in clarifying fundamental principles of gyroscopic motion, and frction has been left out of consideration because the construction, mounting, and casing of modern gyroscopes are such as to keep friction of all kinds as low as possible.

The author is presently Professor Emeritus of Mathematics, United States Naval Academy.

MATERIALS

Differential Thermal Analysis: Theory and Practice. W. J. Smothers and Yao Chiang. New York, Chemical Publishing Co., Inc., 1958. 444 pp., illus., diagrs., tables. $16.

As first developed, differential thermal analysis dealt mainly with minerals and soils, but in recent years the trend has been to use DTA for identification of chemicals so that workers in the fields of chemistry, geology, soil science, ceramics, and metallurgy will find this book useful. This book is the compilation into one volume of information gathered from hundreds of scattered articles and includes such topics as the origins of DTA, DTA equipments, factors in qualitative DTA with some selected applications, theoretical background and applications of quantitative DTA, the use and correlation of DTA results, and recent developments and applications in the field. An attempt has been made to limit discussion and reference to differential thermal analysis as compared to thermal analysis; however, special cases of the latter have been cited.

More than 50 per cent of the book consists of appendixes: (1) Publications on DTA (1,546 items), (2) Information on DTA Equipment, which gives the names of 255 United States and foreign laboratories with pertinent data on each, (3) Index of Operators of DTA Equipment, and (4) Alphabetical Reference List of Materials Studied by DTA.

Mr. Smothers is Director of Ceramic Research, The Ohio Brass Co., and Mr. Chiang is Research Associate in Colloids, Department of Chemistry, Ohio State University.

Rapid Analysis of Nonferrous Metals and Alloys. George Norwitz. New York, Chemical Publishing Co., Inc., 1958. 112 pp. $4.25.

This book differs from previously published works on metal analysis in the following respects: (1) there is an increased reliance on sequence procedures, (2) mathematical correction factors are advantageously used to eliminate lengthy separations, (3) colorimetric procedures are stressed, and (4) increased use is made of perchloric acid, especially in destroying organic matter.

A Symposium on Aluminium and Its Alloys in Electrical Engineering; Convened by the Aluminium Development Association and Held at the Institution of Electrical Engineers, London, May 16–17, 1957. London, The Aluminium Development Association, December, 1957. 369 pp., illus. 20*s*.

The present publication reproduces papers and discussions contributed by a variety of technical interests—mostly from the British electrical industry and from the United States, France, Germany, and Italy.

MATHEMATICS

Introduction to Fourier Analysis and Generalized Functions. M. J. Lighthill. (Cambridge Monographs on Mechanics and Applied Mathematics.) Cambridge, Eng., At the University Press; New York, Cambridge University Press, 1958. 79 pp., diagrs., tables. $3.50.

This monograph, which grew out of an undergraduate course taught by the author at the University of Manchester, employs elementary and uncomplicated treatment throughout and requires little detailed knowledge of mathematical techniques. A particular feature is the use of generalized-function theory to derive a simple, widely applicable method of obtaining asymptotic expressions for Fourier transforms and Fourier coefficients.

MISSILES

Guided Missiles: Operations, Design, and Theory. Sponsored by the Department of the Air Force. New York, McGraw-Hill Book Co., Inc., 1958. 575 pp., diagrs. $8.00.

This volume is a reproduction in book form of *Air Force Manual 52-31* which was compiled in 1955 by the instructors and staff of the Air Training Command's school for missiles at Lowry AFB, Colorado, to serve as a primer for military personnel concerned with the handling and operation of guided missiles. The topics discussed include a brief history of guided missiles and a description of the organization within the United States Air Force which is charged with their development. Aerodynamics, propulsion, instrumentation, and electronic control and guidance systems are covered as they relate to the guided missiles field, and methods are given for the operation, maintenance, and inspection of guided-missile control and guidance systems.

PHOTOGRAMMETRY

Analytical Photogrammetry. Everett L. Merritt. New York, Pitman Publishing Corp., 1958. 242 pp., diagrs., tables. $7.50.

This general analytical treatment of photogrammetry commences with an exposition of the geometric laws of perspective and concludes with the equations for the determination of the position, spatial configuration, and orientation of an irregular object surface without object space control. General explicit and iterative equations are developed for the single and multiple camera stations, and it is shown that any problem is some simplification of the general analytical equations of photogrammetry.

The author is Technical Director, Photogrammetry, Inc.

RESEARCH

The Direction of Research Establishments; Proceedings of a Symposium Held at the National Physical Laboratory on 26–28 September, 1956. New York, Philosophical Library, 1957. 384 pp., illus., diagrs. $12.

Contents: (1) Fundamental and Applied Aspects of Research Problems, J. D. Bernal. (2) The Research Project: Choice and Termination, Willis Jackson. (3) Creativity and the Scientist, Morris Stein. (4) Personality and Social Factors Related to Creativity, D. J. van Lennep. (5) Budgets and Administrative Controls, D. R. Willson. (6) Some Factors Affecting Laboratory Administration, E. S. Hiscocks. (7) Science and Workshop, R. Vieweg. (8) Buildings: What is Required, F. M. Lea. (9) Building for Research; Design, Construction and Layout of Laboratories, H. A. Snow. (10) Selection and Personal Assessment of Staff, W. S. Bristowe. (11) Staff Selection and Assessment, F. T. Rosser. (12) Superiors and Subordinates in Research, Herbert A. Shepard. (13) Staff Groupings and the Flow of Authority, C. R. Harington. (14) Incentives, Stanley Mayne. (15) Internal Communications in a Large Research Laboratory, C. G. Williams. (16) Studies in the Use of Technical Information in the Smaller Industrial Establishments (with Supplement), Louis Moss and L. T. Wilkins. (17) Knowledge: Passing it On—Getting it Used, A. T. Green and A. E. Dodd. (18) Some Fundamental Difficulties in Popularizing Science, M. W. Thistle. (19) Extramural Communications, Arthur Garratt.

ROTATING WING AIRCRAFT

Helicopter Technician. Prepared by Sheppard Air Force Base, Texas. (USAF On the Job Training Program; Program No. JA43170.) Washington, Superintendent of Documents, 1957. 392 pp., diagrs. $2.00.

This packaged program contains the OJT Outline and Training Standard, job knowledge, work experiences, references, and guidance necessary to develop the proficiency required of a Helicopter Technician.

Contents: (1) The Helicopter. (2) Weight and Balance. (3) Aircraft Materials. (4) Bearings. (5) Repair Procedures. (6) Electrical Maintenance. (7) Engine Conditioning. (8) Transmission Systems. (9) Vibrations. (10) Cold Weather Maintenance. (11) Ground Safety. (12) Supplies and Technical Orders. (13) Maintenance Forms. (14) Management. (15) Product Improvement Program. (16) Odds and Ends. (17) Test.

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The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

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Dept. A-39
BELL AIRCRAFT CORPORATION
P.O. Box 1, Buffalo 5, New York.

Available

872. Maintenance and Flight Engineer—Age 32. Heavy experience in aircraft operation, maintenance, and inspection on various light and large types, and 5 years as flight engineer on Lockheed Constellation aircraft in overseas airline operation. Extensive maintenance and flying experience on the Bristol Britannia Mk. 310 aircraft. Also extensive administrative experience and ability. Interested in maintenance, technical representative, flight engineering, or similar position.

871. Aeronautical Engineer—Solid background includes 2 years in aircraft stress, 2 years in the military, and 13 years in engineering education from teaching to administration. Registered mechanical engineer. Consulting engineer. Limited flight experience. B.S. and M.S. in A.E. Available in September.

869. Engineer—M.S. in Ae.E. Eight years' engineering experience in the aircraft industry. Lecturer in heat transfer at a major southern California university. Engineering experience primarily concerned with analytical design and development of pneumatic systems, cabin and equipment conditioning systems, defog systems, turbine-driven auxiliary power systems, etc. Wide experience in heat-transfer analysis, compressible fluid flow analysis, and research and development testing. Present position involves supervision of group responsible for analytical design and development of conditioning and defog systems on a high-performance aircraft. Desires a position of more scope and responsibility, either technical or technical management. Will consider relocation. Complete résumé on request.

868. Engineer—Presently employed in the field of airframe sales; desires an interesting change in export sales. Some 16 years in the aviation business including experience as a pilot, sales and service engineer, and flight-test engineer. Traveled extensively in Europe and the Far East, and has a speaking knowledge of German and Spanish. Many contacts in the commercial airline field, as well as miliary acquaintances. Has worked with NATO, USAF, and BuAer as an engineering consultant in the aviation field. Present salary is above $11,000. Would like a traveling-type assignment, and can relocate at a moment's notice. Detailed résumé forwarded upon request.

867. Aeronautical Engineer—B.S. in Ae.E; Age 33. One year of college teaching experience, plus 8 years' diversified aeronautical experience in aircraft flight handbooks, product research and development (including VTOL), and aerodynamic performance pertaining to a wide variety of piloted aircraft. Last 3 years as aerodynamics group leader. Presently in flight dynamics with a large airframe manufacturer as senior aerodynamics engineer performing development work on varied aircraft types. Thoroughly grounded in aircraft specifications. Desires broader responsibilities and a shift to VTOL aerodynamic development and/or missiles aerodynamics with a progressive company that can offer a career opportunity. Interesting work and growth potential are of paramount importance. Will consider only East Coast location. Résumé forwarded upon request.

866. Contract Management—15 years' experience in engineering and management with large and small aircraft and engine manufacturing companies. One year in project engineering, 3½ years on general manager's staff, and 3½ years on engineering management staff. Last 7 years in contact management areas of program proposals to military services and program planning and management control. Heavy experience in dealing with top engineering, production, accounting, and sales executives. Desires position of greater responsibility with small- or medium-size manufacturer or research center. Prefers eastern Ohio or western New York State location. Now employed by major U.S. corporation. Salary is $7,500 per year. Age 32.

865. Aeronautical Engineer—Desires position in the development of research and engineering subject classifications for airplane and guided-missile information and in other phases of documentation of technical reports; or a position in technical editing and translation. Sixteen years' experience with the Navy Department in organizing and maintaining a bibliographic research office, setting up a system of subject classification, abstracting and reference service, and training personnel in these procedures. Author of *Subject Classification of Technical Reports* and other books for the Navy, and editor of *The Technical Data Digest* for the U.S. Air Force.